Mines and Minerals Division

Ontario Geological Survey
Miscellaneous Paper 132

Summary of Field Work and Other Activities 1986

by the
Ontario Geological Survey

edited by
P.C. Thurston, Owen L. White, R.B. Barlow,
M.E. Cherry, and A.C. Colvine

1986

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Northern Development
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FOREWORD

During 1986, the Ontario Geological Survey carried out a large number of independent geoscience studies. In addition, studies were undertaken in cooperation with regional geological staff, personnel from universities, and private consulting firms. geoscience programs were also undertaken in the Opapimiskan Lake and Black River-Matheson (BRIM) areas and in several areas under the Canada Ontario Mineral Development (COMDA) Agreement. These are summarized in the section at the end of this report. Project involvement by the various participants is summarized in the individual reports. Separate funding for a number of regional stimulation projects was provided and funding acknowledgments are included in the individual summaries.

The locations of the areas investigated are compiled on two maps of the province at the beginning of this report. Preliminary results of field work and other research are outlined in this summary, which contains reports prepared by leaders and principal investigators for each of the projects. In these reports, some emphasis has been placed on the economic mineral resources aspects of the different investigations. The aim of the Ontario Geological Survey is to provide a current database for mineral resource evaluation of these areas, which will be of value in assisting mineral exploration and resource planning in Ontario. In addition, the wide spectrum of research in this report is of interest to the geoscience community as a whole.

Coloured maps and final detailed reports covering most of the field projects are being prepared for publication. In the interim, uncoloured preliminary geoscience maps with comprehensive marginal notes will be released for distribution, mainly during the winter of 1986-1987. Notices of the releases will be mailed to all persons or organizations on the Mineral Resources Group publication release notification list, and will be published in the technical journals and other media.

V.G. Milne
Director
Ontario Geological Survey

ERRATA

Ontario Geological Survey
Miscellaneous Paper 132

Summary of Field Work and other Activities, 1986

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Conversion Factors for Measurements in Ontario Geological Survey Publications

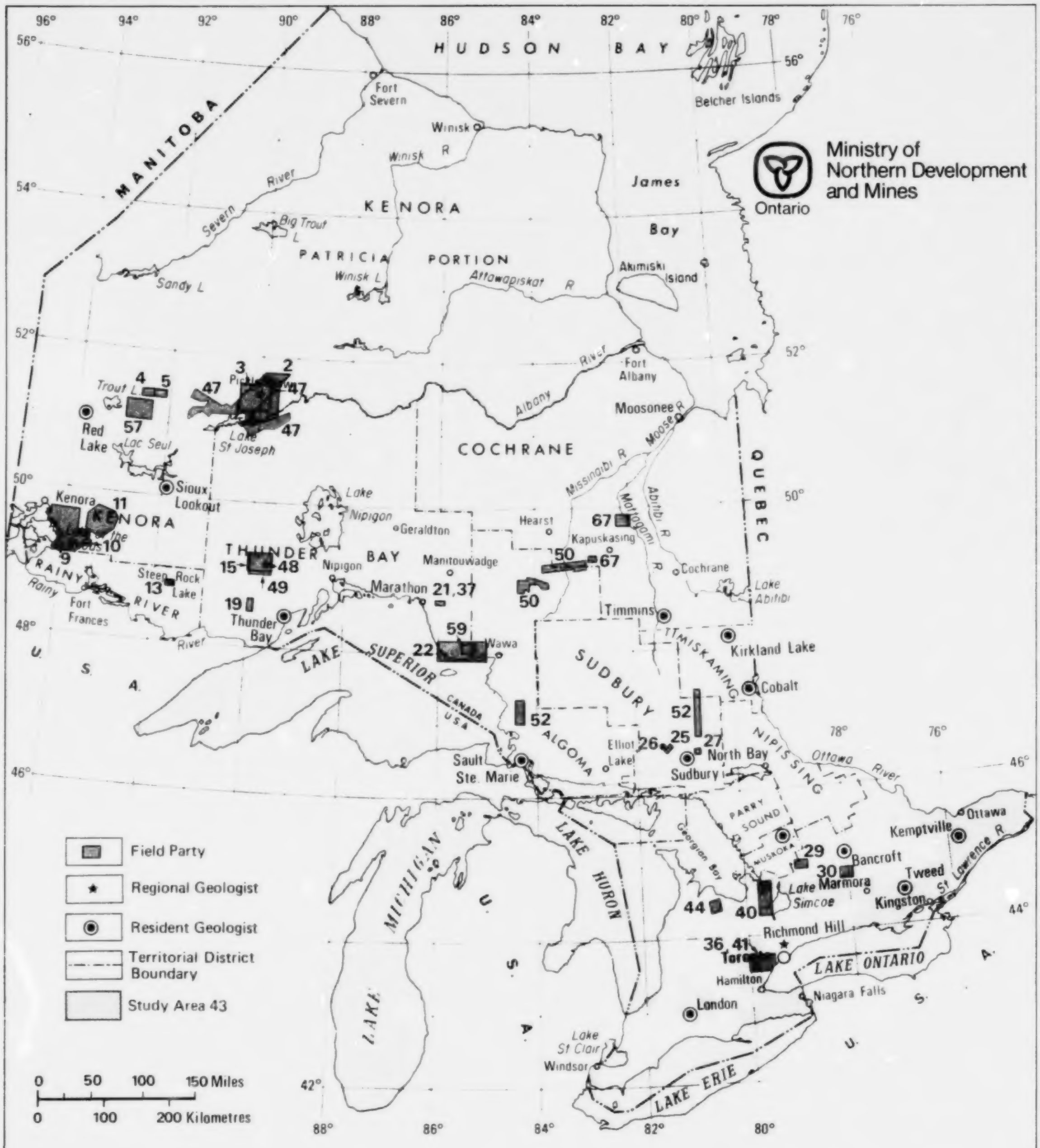
If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm²	0.155 0	square inches	1 square inch	**6.451 6**	cm²
1 m²	10.763 9	square feet	1 square foot	**0.092 903 04**	m²
1 km²	0.386 10	square miles	1 square mile	2.589 988	km²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm³	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm³
1 m³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m³
1 m³	1.308 0	cubic yards	1 cubic yard	0.764 555	m³
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE—Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in cooperation with the Coal Association of Canada.


Ministry of Northern Development and Mines
Ontario
HUDSON BAY
James Bay
Belcher Islands
Akimiski Island
Fort Severn
Winisk
Winisk R
Severn River
Big Trout L
Sandy L
Winisk L
Attawapiskat R
MANITOBA
KENORA
PATRICIA PORTION
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Fort Albany
Moosonee
Moose R
Missinaibi R
Mattagami R
Abitibi R
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Red Lake
Lac Seul
Pickle Lake
Lake St Joseph
Sioux Lookout
Kenora
KENORA
Lake of the Woods
RAINY RIVER
Rainy River
Fort Frances
Steep Rock Lake
THUNDER BAY
Thunder Bay
Lake Nipigon
Nipigon
Geraldton
Manitouwadge
Marathon
Hearst
Kapuskasing
Cochrane
Lake Abitibi
Timmins
Kirkland Lake
Cobalt
TIMISKAMING
Wawa
LAKE SUPERIOR
CANADA
USA
SUDBURY
ALGOMA
Elliot Lake
Sudbury
North Bay
NIPISSING
Ottawa River
Ottawa
Sault Ste. Marie
PARRY SOUND
MUSKOKA
Georgian Bay
Bancroft
Marmora
Tweed
Kemptville
Kingston
St Lawrence R
Lake Simcoe
Richmond Hill
Toronto
Hamilton
LAKE ONTARIO
Niagara Falls
London
Lake St Clair
Windsor
LAKE ERIE
LAKE HURON
LAKE MICHIGAN
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78°
76°
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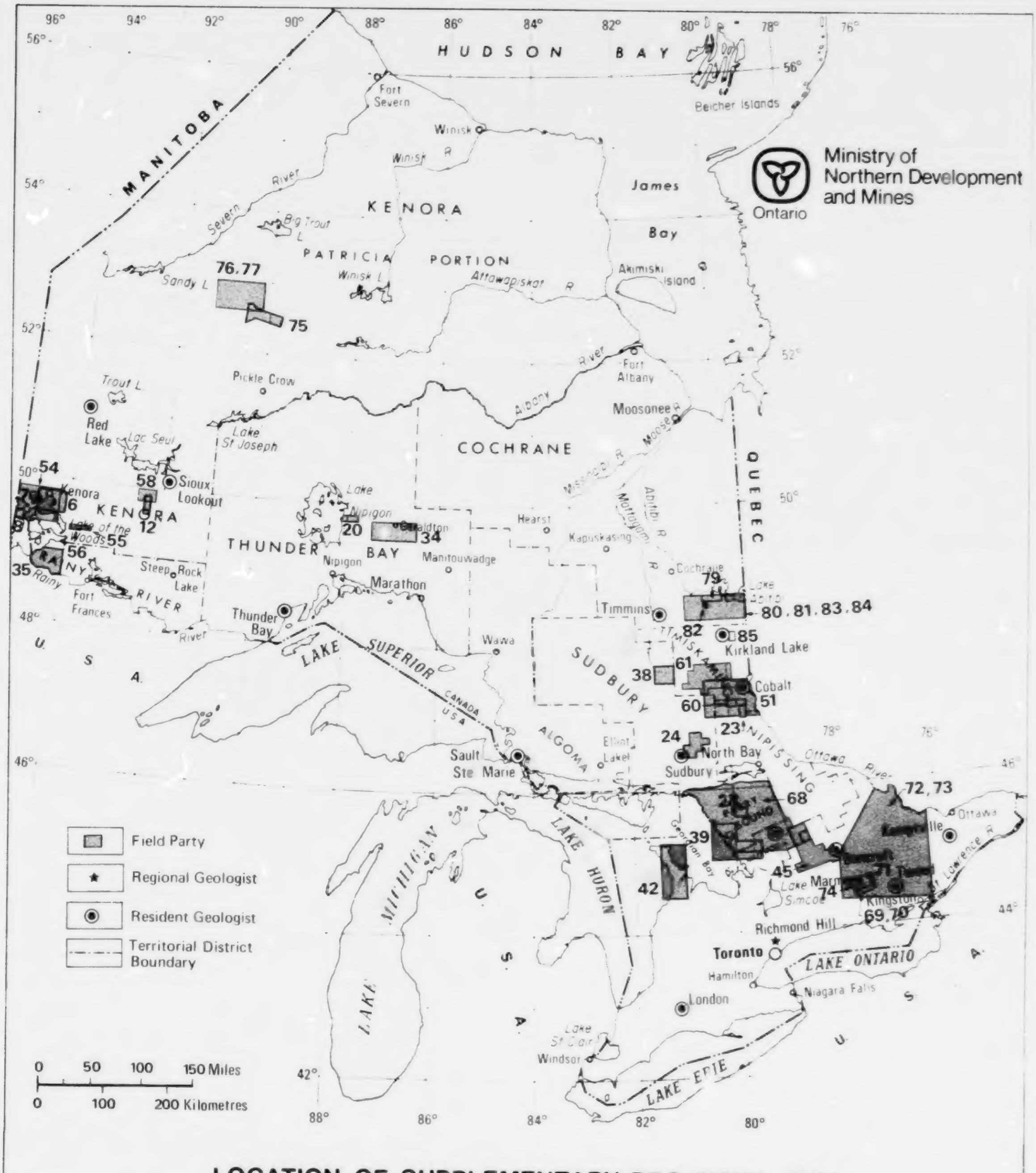
52°
50°
48°
46°
44°
42°
Field Party
Regional Geologist
Resident Geologist
Territorial District Boundary
Study Area 43
0 50 100 150 Miles
0 100 200 Kilometres

LOCATION OF FIELD PROJECTS, 1986

ONTARIO GEOLOGICAL SURVEY


Ministry of Northern Development and Mines
Ontario
HUDSON BAY
James Bay
MANITOBA
QUEBEC
KENORA PATRICIA PORTION
KENORA
COCHRANE
THUNDER BAY
RAINY RIVER
SUDBURY
ALGOMA
NIPISSING
TIMISKAMING
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
U.S.A.
CANADA
Fort Severn
Winisk
Belcher Islands
Akimiski Island
Fort Albany
Moosonee
Pickle Crow
Red Lake
Sioux Lookout
Kenora
Fort Frances
Thunder Bay
Nipigon
Geraldton
Marathon
Manitouwadge
Hearst
Kapuskasing
Cochrane
Timmins
Kirkland Lake
Cobalt
Wawa
Sault Ste Marie
Elliot Lake
Sudbury
North Bay
Ottawa
Kingston
Richmond Hill
Toronto
Hamilton
Niagara Falls
London
Windsor
54
58
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80,81,83,84
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72,73
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45
74
69,70
Field Party
Regional Geologist
Resident Geologist
Territorial District Boundary
0 50 100 150 Miles
0 100 200 Kilometres

LOCATION OF SUPPLEMENTARY PROJECTS, 1986

MINISTRY OF NORTHERN DEVELOPMENT AND MINES, ONTARIO
MINISTRY OF TREASURY AND ECONOMICS, ONTARIO
ENERGY, MINES AND RESOURCES, CANADA

PRECAMBRIAN GEOLOGY PROGRAMS

001. Summary of Activities 1986, Precambrian Geology Section

P.C. Thurston

Acting Chief Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto

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During the 1986 field season the Precambrian Geology Section undertook 26 field-based projects. Twenty-two projects were led by permanent and contract staff of the Section, two by university graduate students, and two by university staff. Of the above field-based projects, 17 involve detailed mapping, generally at 1:15 840, one is 1:50 000 regional scale mapping, one is a 1:50 000 scale regional synthesis (involving some detailed mapping), and seven are thematic projects. Several projects involved production of more than one summary. As well, two papers represent progress reports on ongoing nonfield-based projects.

The basic building block of database geological mapping is the 1:15 840 scale mapping which provides a detailed appraisal of mineral potential and is fundamental to government and private sector planning. Most detailed mapping projects represent part of longer term database mapping programs to assess the mineral potential of large blocks of high mineral potential land. Thematic projects, such as the Lac des Iles project, are part of a multi-year program designed to determine the distribution, genesis, and mineral potential of mafic and ultramafic intrusions in the Wabigoon Subprovince and have essentially geological goals. These geological goals, however, are always predicated upon a direct relationship to mineral deposit geology. Reconnaissance projects take a wider scale geological perspective in order to provide the broadest possible overview of the place of mineral deposits in a regional context. Regional synthesis projects generally follow upon several projects of detailed mapping. These syntheses are designed to develop regional scale units which then permit a broad scale view of the interrelationship of stratigraphy, structure, and mineral deposits to be developed. The synthesis projects permit the intelligent joining of map sheets produced by several geologists over a period of years. Some thematic projects may not involve mapping. Instead, the projects may involve laboratory or computer-based studies, or the integration of a series of field observations into a conceptual model for a mineral deposit, a geological unit, or an area.

The projects reported upon on a yearly basis are part of a multi-year strategic plan for the geological mapping of the Province of Ontario. The strategic plan is designed to: a) provide a continuously updated geological database on the Precambrian bedrock of Ontario; and b) provide guidance and encouragement of private sector mineral exploration within the Province, with a continuing awareness of the economic and geological factors affecting private sector decisions in the mineral exploration sphere. Given the limited personnel and resources of the Section, some database mapping will inevitably become rather dated. However, a number of the thematic projects are designed to get around this difficulty by addressing problems/mineral deposit types on an essentially geological basis. Through dealing directly, for example, with ultramafic intrusions, effort can be concentrated on a single problem spanning, in this case, intrusions several hundred kilometres apart.

The Ontario Ministry of Northern Development and Mines was officially created April 1, 1986, from the Ministry of Northern Affairs and Mines which resulted from the incorporation of the mines function of the Ministry of Natural Resources within the former Ministry of Northern Affairs. The Ontario Ministry of Northern Affairs provided multi-year funding for several projects: the Opapimiskan Lake Interdisciplinary Project (Breaks *et al*, Project 075); and the Birch Lake (east half) Project (D.J. Good, Project 005). The Ministry of Natural Resources and the Ministry of Northern Development and Mines have equally funded the Black River-Matheson (BRIM) interdisciplinary program (R. Johnstone, Project 079).

The Governments of Canada and Ontario signed a five-year agreement to fund community-based mineral development projects within Ontario called the Canada-Ontario Mineral Development Agreement (COMDA). This year the Precambrian Geology Section has had six projects funded from this source. During the remaining three years of the agreement, COMDA-funded projects of this Section will be placed in the following areas: Kenora-Fort Frances, Ignace, Beardmore, and Sudbury-Cobalt.

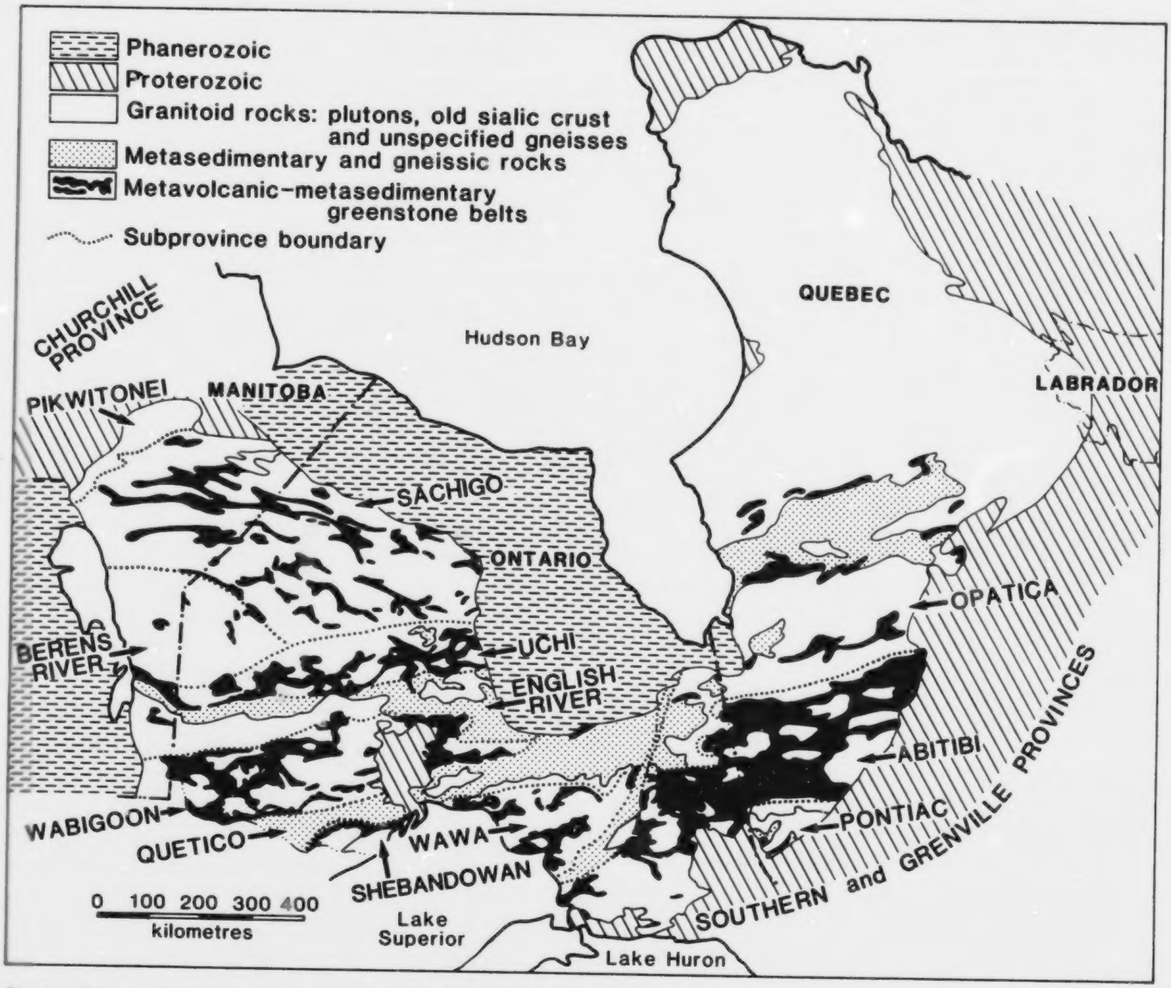
Phanerozoic
Proterozoic
Granitoid rocks: plutons, old sialic crust and unspecified gneisses
Metasedimentary and gneissic rocks
Metavolcanic-metasedimentary greenstone belts
Subprovince boundary
CHURCHILL PROVINCE
Hudson Bay
QUEBEC
LABRADOR
PIKWITONEI
MANITOBA
SACHIGO
ONTARIO
OPATICA
BERENS RIVER
UCHI
ENGLISH RIVER
ABITIBI
WABIGOON
QUETICO
WAWA
PONTIAC
SHEBANDOWAN
SOUTHERN and GRENVILLE PROVINCES
0 100 200 300 400
kilometres
Lake Superior
Lake Huron

Figure 001.1. Sketch map of the Superior Province showing major lithologic and subprovince boundaries.

The locations of field crews are shown on the figures at the front of this volume. They range from the northwest in the Pickle Lake-Red Lake area to the southeastern part of the Province in the Minden area. Section projects embrace rocks of Archean and Proterozoic age. The following overview of the Section program is based upon individual subprovinces of the Superior Province tectonostratigraphic subdivisions of the Canadian Shield shown on Figure 001.1.

SACHIGO SUBPROVINCE

The Opapimiskan Lake interdisciplinary project is the only project within the Sachigo Subprovince. This project entered the third and final year of mapping under Fred Breaks and Ikram Osmani, and completed coverage of the southeastern part of the North Caribou Lake Greenstone Belt. In this work they have traced a distinctive suite of quartz-rich metasediments, komatiite, and iron formation most of the length of the Opapimiskan-Forester Lake portion of the belt. This stratigraphic package may have potential for regional correlation involving the North Spirit Lake, Muskratdam Lake, and the North Caribou Lake Greenstone Belts: (*see* Wood *et al.* 1986). They have noted four types of gold mineralization, including an unusual association of gold in granitic pegmatite dikes associated with rare metals (Li, Rb, Ta, and Sn). This association has not previously been reported in the Superior Province.

UCHI SUBPROVINCE

The Precambrian Geology Section has had a continuing program of detailed and reconnaissance mapping in the western part of the subprovince over the past 15 years. The program began with detailed mapping in the Red Lake area, successively involving Ray Riley, Jim Pirie, and Henry Wallace. Wallace is currently synthesizing work in this camp which will integrate field work of a number of mappers with recently completed geochronological investigations (Corfu and Wallace 1986; Corfu and Andrews, in press). Work in the Birch-Uchi-Confederation Lakes part of the Subprovince has involved Pryslak, Thurston, Beakhouse, and Good. This has resulted in the erection of a general stratigraphic framework centred on Confederation Lake, connected in recently published maps with the Red Lake Belt and its extension in an open file report to the Birch Lake area. Work by Greg Stott over the last four years within the central part of the Subprovince has resulted in the development of a general stratigraphic scheme for the Meen Lake-Lake St. Joseph Greenstone Belt.

This year's mapping program in the Uchi Subprovince involves detailed mapping by two field parties in the Birch Lake area and 1:50 000 scale mapping extending from Lake St. Joseph to north of Pickle Lake. Location of these projects is based both on the intensity of exploration effort in Pickle Lake and Birch Lake, and the need to supplement the decline of iron mining at Ear Falls. The aim of the Uchi Subprovince program is to produce, under the supervision of Norm Trowell, a stratigraphic and structural model at the subprovince scale. With this goal in mind, Greg Stott and Henry Wallace have supervised the collection, by the Jack Satterly Geochronology Laboratory of the Royal Ontario Museum, of several samples for U-Pb zircon geochronology.

In the Birch Lake area (west half), Gary Beakhouse has advanced northward from the 1985 map area. This work has delineated the major supracrustal and intrusive units and a major extension and series of splays off the Swain Lake Deformation Zone. Dave Good, working in the adjoining east half of the Birch Lake area, has described extensive areas of inverted stratigraphy, and east- and northwest-trending shear zones. Spatially associated carbonate and chlorite alteration, quartz veining, and sulphide mineralization with potentially economic assay results suggest that the area has good gold potential.

Greg Stott's project this year included reconnaissance mapping of the classical Pickle Lake gold camp, dividing the area into three lithotectonic domains. Gold mineralization at Pickle Lake is localized along shear zones within Domain 1, whereas the Dona Lake Gold Deposit and the Thierry Copper-Nickel Deposit are related to later developing shear-zones. Greg Stott and Heather Brown have recognized three types of shear zones in the area, similar to the pattern observed in the Red Lake gold camp.

WABIGOON SUBPROVINCE

The western Wabigoon Subprovince (west of Lake Nipigon) has been the site of intense mapping efforts by the Precambrian Geology Section over the last 15 years. Initial work by Blackburn, Davies, and Trowell has been followed by the work of Johns, Jackson, Fumerton, Page, Edwards, Wood, and numerous university-based projects. The essentially stratigraphic work has been tied together with the superb geochronologic work of Don Davis of the Royal Ontario Museum and a geochemically based correlation program by Trowell and Blackburn. These efforts have been recently reviewed by Blackburn *et al.* (1985).

The program in the western Wabigoon Subprovince includes the funding under COMDA of two detailed mapping projects and a structural mapping project in the Lake of the Woods area. While the area has good mineral potential, as one of the larger greenstone belts, there has been a lack of recent mapping. As the culmination of mapping over the last ten years by several geologists east of Lake of the Woods through to Rowan Lake, a regional synthesis project is placing the previous work into an integrated stratigraphic framework. The program of investigation of Wabigoon Subprovince mafic/ultramafic intrusions continues with a second year of investigations in the Lac des Iles area north-northeast of Thunder Bay. A multidisciplinary team involving efforts of the Precambrian Geology, Mineral Deposits, and Geophysics/Geochemistry Sections of the Ontario Geological Survey, has been launched with COMDA funding in the Ignace area. The Precambrian component has involved detailed mapping of three townships between Ignace and Sioux Lookout.

The eastern Wabigoon Subprovince (i.e. east of Lake Nipigon, the Beardmore-Geraldton gold camp) had one detailed mapping project with COMDA funding.

John Ayer, who has mapped the Bigstone Bay and Rat Portage Bay areas (northeastern Lake of the Woods) continued westward with detailed mapping of the Clearwater Bay area with COMDA funding. The major lithologies of previous areas to the east persist westward. The Crowduck Lake-Rush Bay-Witch Bay shear zone continues into the Clearwater Bay area. Gold mineralization occurs: a) within the main shear zone; b) within splays off the main shear zone; and c) north of the main shear zone. Martin Morrice worked (COMDA funding) at a detailed scale in the Monument Bay area, bounded by the U.S. border and the Manitoba border, in southwestern Lake of the Woods. Within this area he noted the presence of two regional scale deformation (shear) zones and the presence of sizable units of basaltic komatiite and late, subaerial hornblende-phyric alkalic basaltic flows. These observations may bring attention to this sparsely explored area. Mary Sanborn worked under the COMDA program in central and northeastern Lake of the Woods. The goal of the project is to develop a tectonic model for the greenstone belt, establishing the mechanics of the shear zones, relative timing of structural, intrusive, and extrusive events, to eventually provide a geochronological framework for the area. These observations are being related to the relative timing of the mineralizing events to arrive at a comprehensive tectonic model. Early results suggest that most structures are related to a late regional scale "transpression" event (*see* Stott 1985).

Glen Johns' regional synthesis project east of Lake of the Woods integrates previous mapping by him with that of Garth Edwards, Les Kaye, John Davies, and Norm Trowell. The principal conclusions are stratigraphic, suggesting that the Rowan Lake Volcanics (mafic flows) underlie the Cameron Lake Volcanics, a collection of mainly felsic pyroclastic rocks. The latter unit is cut by the Monte Cristo Shear Zone, which hosts the Monte Cristo gold deposit. Additional gold occurrences in the area are described. Part of this area was mapped in detail by Kathy Chivers who has refined the stratigraphy of the mafic volcanic sequence, subdividing the sequence into a lower mafic sequence and an upper unit: the Cameron Lake Volcanics, which is a mixed mafic-intermediate sequence; and the Hill Lake Volcanics, which are largely mafic in character.

Garth Edwards (University of Saskatchewan) and Don Davis (University of Toronto/ROM) continued work on the Lawrence-Atikwa Batholith. Their work has attempted to define the petrological and temporal relationships between the many plutons of the Lawrence-Atikwa Batholith. The work has shown some batholith components, late dikes in particular, to be a product of the mixing of mafic and felsic magma, possibly pointing to a massive underplating scenario in late Archean time.

Ben Berger mapped the Melgund Lake area, consisting of three townships, as the Precambrian Geology component of a multidisciplinary COMDA-funded study of the Ignace area. The area straddles the Wabigoon fault and lies immediately south of the Goldlund Gold Deposit. Three environments for gold deposits within the area are identified.

Where university based geologists have worked in close association with Ontario Geological Survey staff, progress reports on their research are published in this volume. Maureen Wilks, a graduate student at the University of Saskatchewan, has worked at Steeprock Lake over the last two years. Results of her study include the development of a definite stratigraphy for the Steeprock Group. Most importantly, she has documented the unconformity between sedimentary rocks of the Steeprock Group and the underlying Marmion Complex, considered as 3 Ga basement to the greenstone belt. When viewed together with the work of Thurston and Davis (1985), further work on greenstone-granite relationships in the area of the Wabigoon Diapiric Axis is definitely required.

Richard Sutcliffe embarked in 1984 on a multi-year program on mafic-ultramafic intrusions in the Wabigoon Subprovince. After mapping the Mulcahy Gabbro in 1984, he commenced work in 1985 on the Lac des Iles complex. Because of current interest in platinum group elements (PGE), this year's program included the completion of a 1:50 000 map sheet which suggests that the locus of intrusions is controlled by the intersection of regional scale east-northeastand north-trending faults. Within the map sheet a new gabbro intrusion at Buck Lake is described. E. Linhardt, in conjunction with Sutcliffe, did detailed mapping of the northern ultramafic part of the Lac des Iles complex. He describes new PGE and chromite occurrences within the complex. Allan Smith and Richard Sutcliffe have described the layered Tib Lake intrusion in detail, including two previously unknown occurrences of PGE mineralization. Mike Sweeny and Richard Sutcliffe have done a detailed study of the Roby Zone mineralization in the Lac des Iles complex. This joint Ontario Geological Survey-University of Western Ontario 1:2400 (1 inch to 200 feet) scale mapping and research project suggests that the mineralization is due to magma mixing between two gabbro units.

Dave Kresz mapped Pifher, Meader, and Barbara Townships in the Beardmore-Geraldton area. He has convincingly demonstrated that it is possible to determine facing directions in the felsic metavolcanics and hence, with time, the large scale structures will be worked out. The gold potential of the area is increasing, with some new occurrences noted.

ABITIBI–WAWA–SHEBANDOWAN SUBPROVINCE

The Abitibi Subprovince is continuous from beyond Chibougamau, Quebec, to northern Minnesota. East of the Kapuskasing Structural Zone (KSZ) is the Abitibi Sector, west of the KSZ is the Wawa Sector, and rocks west and south of Nipigon form the Shebandowan Sector.

SHEBANDOWAN SECTOR

The Precambrian Geology Section recommenced mapping in this sector after a nearly 20-year absence in 1984. Detailed mapping since then has occurred west and east of Thunder Bay. Regional scale work on the Lakehead-Atikokan map sheet has been active, albeit at a low level, since 1983.

Maurice Carter mapped the majority of Blackwell and Laurie Townships west of Thunder Bay in 1986. The northern fringe of the area is underlain by Quetico metasediments separated by a major shear zone from "Keewatin" mafic and ultramafic metavolcanics which border a central felsic volcanic complex, all overlain by "Timiskaming" metasediments and metavolcanics. The area has potential for base metals, gold, and silver.

WAWA SECTOR

The mapping program within the Wawa Sector has continued for a number of years, with approximately 12 townships being fully covered to date, largely by Ron Sage, with additional work by Massey, Downes, and Mandziuk, all in the immediate Wawa area. To the southwest, in the Mishibishu Lake area, Paul Bowen is in the second year of a helicopter supported mapping program. The discoveries at Hemlo have sparked a multi-year reexamination of the area. Giorgio Siragusa has produced preliminary maps for a number of areas to the west and north of the deposits and is currently writing up the results of these projects. Tom Muir is at the midpoint of a multi-year program of detailed mapping in the immediate vicinity of the Hemlo deposits. The goal of the project is to put the deposits into a lithological and structural framework, integrating results from mapping the various properties, and university-based research results.

Paul Bowen continued in the second year of the Mishibishu program. This work has resulted in the mapping of the southeastern part of the area. Exploration activity in the area suggests that there is good potential for gold deposits.

Tom Muir continued work close to the Hemlo deposits. His work is beginning to show the relationship between alteration processes, such as feldspathization, and structural processes. Mineralization is now seen clearly to cross-cut stratigraphy, suggesting that syngenetic models may have been premature.

ABITIBI SECTOR

The Abitibi Subprovince east of the Kapuskasing Structural Zone has received intense attention over the last twenty years with many years of mapping by Jensen, Pyke, and numerous contract geologists. As well, Giblin, Siragusa, and Grunsky have been active in the Batchawana area. Grunsky will soon release preliminary maps from a regional synthesis of the area, and an article on the geochronology of the area by Fernando Corfu of the Royal Ontario Museum will appear shortly. Preliminary maps of an area near Kirkland Lake, by Larry Jensen, will appear this year.

This year's program included only the MNR-MNDM supported Black River-Matheson (BRIM) program. This years work has shown the three townships covered to be underlain by rocks of the Hunter Mine, Stoughton-Roquemaure, and Porcupine Groups. Facies relationships within the Hunter Mine Group suggest it to be a distal facies felsic volcanic-sedimentary package. Numerous gold and base metal prospects occur in the area.

SOUTHERN PROVINCE

The Southern Province has been the site of considerable work by numerous workers in the last few years. Precambrian Geology Section work by Dressler has spawned some subprojects being investigated as thesis projects.

This year, five projects occurred in the Southern Province, three in the Sudbury area, one in the Huronian north of Sudbury, and one east of Temagami in Archean and Proterozoic rocks. Burkhard Dressler mapped part of Falconbridge Township with a view to understanding the relationships between Huronian units and the Sudbury Igneous Complex, which hosts the copper-nickel deposits. The granophyre of the complex is strongly deformed, while other units slightly to undeformed, suggesting that the granophyre is older. Further work on the field relationships and geochronology are called for.

Peter Brockmeyer and Rolf Lakomy are investigating the Onaping Formation and the Footwall Breccia of the Sudbury Igneous Complex. The Footwall Breccia fragment population differs significantly from the clasts of the Onaping Formation. Volker Mueller-Mohr is investigating the Sudbury Breccias near Levack, and along a 65 km section of Highway 144 northwest of Windy Lake.

Maria Elisabeth Avermann is examining the contact metamorphism of the Footwall Breccia of the Sudbury Igneous Complex. In the study, it is hoped to be able to distinguish between Archean and Proterozoic metamorphic events.

Peter Born mapped Cassels and Riddell Townships east of Temagami where the eastern end of the Archean Temagami Greenstone Belt is overlain by Middle Proterozoic Gowganda and Lorrain Formations and cut by Nipissing diabase sills. Copper, gold, and silver mineralization occurs near the contact between the Nipissing diabase and the Coleman Member of the Gowganda Formation, a situation reminiscent of the Cobalt camp.

GRENVILLE PROVINCE

The Precambrian Geology Section has had a continuing program in the Grenville Province for over twenty years. Based on the pioneering work of Don Hewitt and Jack Satterly, a continued program with Sid Lumbers existed for a number of years. Since then numerous mappers including Bright, Wolff, Themistocleous, Pauk, Moore, and Culshaw, have completed projects in the Grenville Province. Bright and Easton have been mapping in the Grenville Province for the last few years. The program this year includes the continuation of work in the Minden area by Easton, and work in the Parry Sound area toward the Grenville Front by Bright.

Mike Easton's project in the Anson area lies along the boundary between the Central Metasedimentary Belt Boundary Zone and the Central Gneiss Belt. The area has potential for base metals, gold, magnesium carbonate, building stone, flagstone, aggregate, and crushed stone. The Apsley Gneiss or Apsley Formation, part of the Hermon Group within the Central Metasedimentary Belt of the Grenville Province, has many primary features which suggest that it is of mixed metavolcanic-metasedimentary origin. In a thorough, thought provoking analysis of relict primary textures and structures, Easton suggests that the unit originated as a pyroclastic fan similar to the turbidite fan depositional model. As such, the unit has potential for disseminated base metal deposits.

Ted Bright mapped extremely deformed gneisses of the Central Gneiss Belt which form numerous domains with variable lithologies, structural styles, and metamorphic grades. Anorthosites within the area are potential targets for deposits of vanadium, chromium, and platinum group metals. Numerous rare metals and industrial minerals are potential exploration targets as well.

Ruth Debicki is attempting to assess the potential of the southern Cobalt embayment for Witwatersrand type gold deposits. She has measured a number of stratigraphic sections through the Huronian rocks immediately to the northeast of Sudbury. At some locations, pyritic orthoconglomerates of the Mississagi Formation may have gold potential.

COMPUTER SOFTWARE

The Survey attempts to make public all computer programs, created in the course of our investigations, which may be of help in the mineral exploration process. In the last year we have completed the transition of our geochemical data plotting routines from a minicomputer to DOS-based microcomputers. This volume includes a summary, by Elizabeth Ambrose, on the available programs. The routines, which are in the general area of geochemical plotting, structural plotting, and retrieval of various types of data from machine-readable field notes, are being tried on some Precambrian Geology programs. A major change involves being able to determine silicate liquid densities from geochemical data, which is of use in the modeling Archean volcanic processes (Thurston and Sutcliffe 1986).

The last report in the Precambrian Section's portion of the volume is an interim report of the internal committee charged with the development of a new scheme for a chemically based classification of Archean volcanic rocks. The approaches used by Eric Grunsky and co-authors are correspondence analysis and dynamic cluster analysis. This heavily statistical approach will be supplemented later in the investigation by a new series of more readily usable binary and ternary diagrams. When the work is further advanced, the supporting programs will be released for use.

The reports in this volume represent a first synthesis of incompletely digested field data. As analysis proceeds, preliminary maps will be produced during the Winter of 1986-87. The summaries and sketch maps in the volume represent an effort to rapidly disseminate the essential features of the 1986 summer field program. More extended analysis will be supplied through production of preliminary maps and open file reports. During this laboratory and office study, there will inevitably be changes in the nomenclature, interpretation, and concepts that are advanced in this volume.

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002. Regional Geology and Structure of the Pickle Lake Metavolcanic Belt, District of Kenora, Patricia Portion

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INTRODUCTION

This report summarizes the principal results of a three-year reconnaissance survey of the Pickle Lake Metavolcanic Belt in the central part of Uchi Subprovince (*see* Stott and Wallace 1984; and Stott 1985).

Approximately 2000 km^2 were mapped at a scale of 1:50 000 in the Pickle Lake area, including major granitoid intrusions within, and adjacent to, the metavolcanic belt. Bedrock exposure is highly variable. Large parts of the belt display little or no outcrop. The best exposure is seen along a broad northeast-trending area through the old Pickle Crow gold camp. The limited exposure across the belt has been a major impediment to gold exploration and on the ability to trace the regional stratigraphy.

An effort has been made in this program to consult the various exploration companies operating in this region, and to compile information from recently submitted drill logs and other data from the Assessment Files of the Resident Geologist's Office, Sioux Lookout.

The results provide a modest revision of a previous reconnaissance survey (Sage and Breaks 1982) and earlier mapping of the metavolcanic belt by Hurst (1931), Thomson (1939), Evans (1941), Ferguson (1966) and Pye (1976). In addition, the author presents a subdivision of the adjacent granitoid complexes into several intrusive units. A summary is given of the tectonic sequence of events encompassing the Pickle Lake Belt and adjacent granitoid rocks.

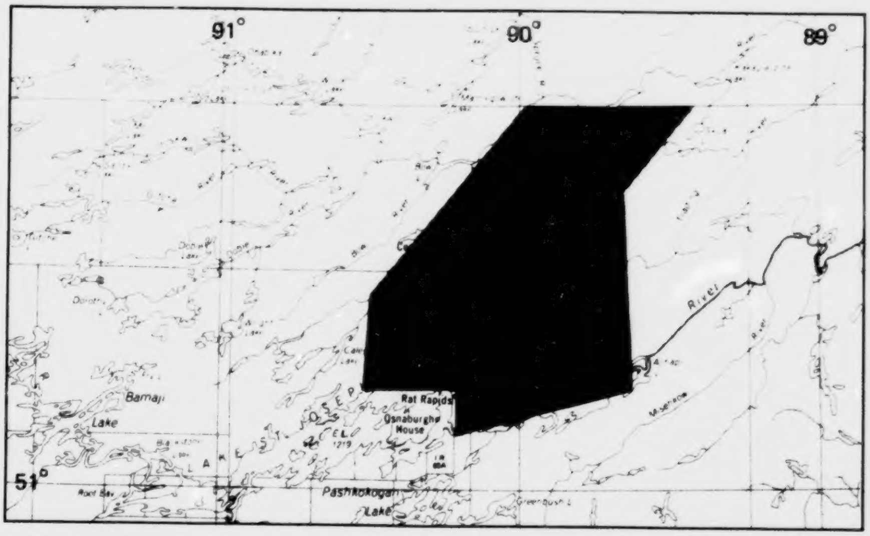
Several gold occurrences and properties that are presently being developed have been examined and the structural geology of some of these are related to the overall tectonic history of the area in an accompanying report (*see* Stott and Brown, this volume).

GENERAL GEOLOGY

Owing to the scarcity of outcrop in many parts of the Pickle Lake Belt, and the widespread lack of reliable stratigraphic younging indicators, it has not been possible to provide a satisfactory stratigraphic-structural framework for the entire belt, nor as yet to complete the correlation of stratigraphic units with the volcanic cycles defined in the Meen-Dempster Lakes Belt to the southwest (Stott and Wilson 1986). This correlation problem is presently being analyzed using the airborne geophysical survey results contracted by the Ontario Ministry of Northern Development and Mines and published in the Fall of 1986. In addition, a U-Pb zircon dating program is presently being conducted across the central Uchi Subprovince to establish a time framework for the regional stratigraphy and the tectonic history.

SUPRACRUSTAL ROCKS

The general geology of the Pickle Lake Belt is summarized in Figure 002.1. This metavolcanic belt is dominated by massive to pillowed basaltic flows. The rocks are typically fine grained but coarse-grained flows are locally prominent, notably east of the Ochig Lake Pluton on the Dona Lake gold Property held, jointly by Dome Mines Limited and Campbell Red



LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

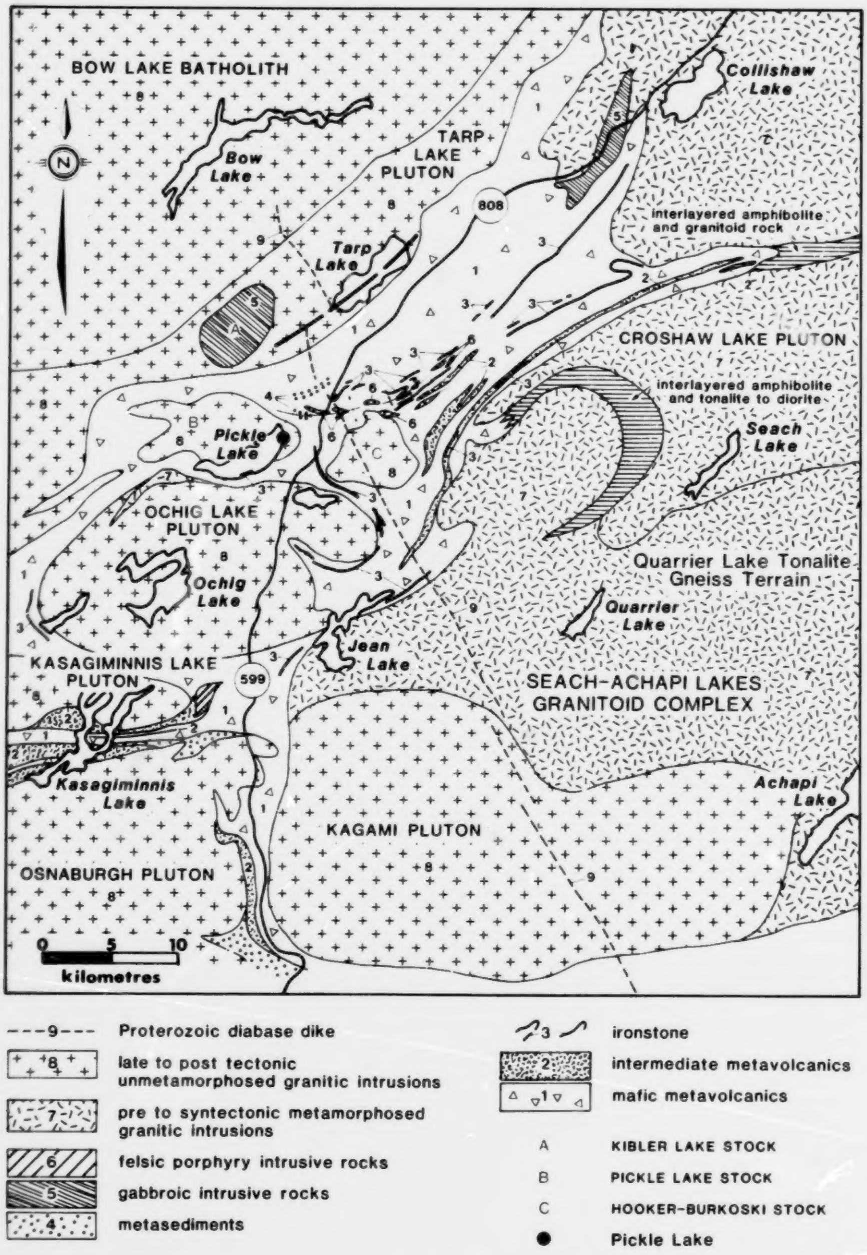

BOW LAKE BATHOLITH
Bow Lake
N
TARP LAKE PLUTON
808
Collishaw Lake
Tarp Lake
interlayered amphibolite and granitoid rock
CROSHAW LAKE PLUTON
interlayered amphibolite and tonalite to diorite
Seach Lake
Pickle Lake
OCHIG LAKE PLUTON
Ochig Lake
Quarrier Lake Tonalite Gneiss Terrain
Quarrier Lake
Jean Lake
KASAGIMINNIS LAKE PLUTON
599
SEACH-ACHAPI LAKES GRANITOID COMPLEX
Kasagiminnis Lake
Achapi Lake
KAGAMI PLUTON
OSNABURGH PLUTON
0 5 10
kilometres
9 Proterozoic diabase dike
8 late to post tectonic unmetamorphosed granitic intrusions
7 pre to syntectonic metamorphosed granitic intrusions
6 felsic porphyry intrusive rocks
5 gabbroic intrusive rocks
4 metasediments
3 ironstone
2 intermediate metavolcanics
1 mafic metavolcanics
A KIBLER LAKE STOCK
B PICKLE LAKE STOCK
C HOOKER-BURKOSKI STOCK
● Pickle Lake

Figure 002.1. General geology of the Pickle Lake area.

Lake Mines Limited. Limited volumes of dacitic to andesitic tuff and flow rocks are observed south of Pickle Crow, along the southeastern side of the belt, and in the Kasagiminnis Lake area. Lapilli and bomb size clasts are only locally observed south of Pickle Crow and on Kasagiminnis Lake.

Long, continuous marker units of magnetite-chert ironstone, interbedded with greenish mudstone, occur most typically within mafic metavolcanics. Ironstone also occurs locally within an intermediate tuff unit near the eastern margin of the belt.

The interbeds of greenish mudstone and local graphitic schist associated with the ironstone units are extensively ferroan dolomitized in the vicinity of the Village of Central Patricia and the former settlement of Pickle Crow. This alteration is spatially associated with pervasive carbonatization of the volcanic rocks. Such extensive alteration of rocks occurs in two zones shown schematically in Figure 003.2 of Stott and Brown (this volume).

Very few clastic metasediments are observed in this belt apart from units in the southern part of the map area east of Kasagiminnis Lake and on Highway 599 (Figure 002.1).

Within the metavolcanic assemblage, gabbroic sills are not easily distinguished from coarse basaltic flows. A large gabbroic intrusion lies adjacent to the northern end of the belt, southwest of Collishaw Lake. Gabbroic and ultramafic intrusive sheets occur north of the Pickle Lake Stock and host the copper-nickel deposit at the Thierry Mine. Very little is known about the circular Kibler Lake Stock that intruded into the Tarp Lake Pluton. Sage and Breaks (1982, p.193-194) report that the outer part of this apparently multiphase or layered intrusion with a donut-shaped aeromagnetic signature (ODM-GSC 1960) is at least locally composed of magnetite-rich melanocratic diorite.

Lenticular quartz porphyry intrusions occupy a significant volume of the stratigraphy in the Central Patricia-Pickle Crow area. These bodies are all somewhat similar, with quartz eyes in a variably deformed and sericitized fine-grained matrix. The rocks are locally sheared and in places contain inclusions of mafic metavolcanics and ironstone.

A schistose quartz- to quartz-feldspar porphyry intrusion lies east of the Kasagiminnis Lake Pluton and flanks a major unit of intermediate pyroclastic rocks. These pyroclastic rocks strike westward and may correlate with the intermediate metavolcanics of the Dempster Lake cycle observed at the northern end of Caley Lake, west of the present map area (*see* Stott and Wallace 1984; and Stott and Wilson 1986).

GRANITIC ROCKS

The western half of the Seach-Achapi Lakes granitoid complex has been subdivided into several major components (Figure 002.1). The names of this complex and the intrusive subdivisions within it are given here for the first time. The central core of this complex is composed of the oldest granitoid rocks—the Quarrier Lake tonalite terrain. These fine-grained foliated to gneissic tonalites, which contain local zones of amphibolite inclusions, may comprise more than one intrusion. The tonalite is metamorphosed and recrystallized. It is more strongly deformed near the contact with the younger, slightly metamorphosed Croshaw Lake Pluton. This younger quartz-phyric tonalite pluton forms an arcuate, crescent-shaped body 16 km wide which borders and intrudes both the metavolcanic belt to the north and the tonalitic gneisses to the south and west (Figure 002.1). Both the gneissic terrain and the Croshaw Lake Pluton are crosscut by younger granite pegmatite dikes.

The youngest intrusion in the granitoid complex is the Kagami Pluton. This slightly arcuate, "boot-shaped" pluton appears to have invaded along a pre-existing arcuate boundary between the metavolcanic belt and the older Quarrier Lake tonalite. The pluton is unmetamorphosed and comprises a dominant quartz-phyric granodiorite phase and a narrow marginal phase of fine-grained, equigranular granodiorite. The internal pattern of foliation and shallowly-plunging mineral lineations is consistent with that of a primary magmatic fabric formed during emplacement of a synformal crescent-shaped sheet intrusion (Schwerdtner *et al.*1983).

Northwest of the Pickle Lake Belt is a large granitoid terrain which straddles both the Uchi and Sachigo Subprovinces. This terrain is dominated by an immense, apparently single phase intrusion, referred to here as the Bow Lake Batholith, which spans up to 55 km in width. This body is composed of medium- to coarse-grained potassium-feldspar megacrystic monzogranite to granodiorite. There is an abundance of visible magnetite crystals throughout the batholith, which produces the high magnetic intensity (typically >61 000 nT (gammas)) that characterizes this intrusion.

Immediately adjacent to the Pickle Lake Belt is the unmetamorphosed late to post-tectonic Tarp Lake Pluton. This body has imposed only a very narrow contact strain aureole upon the adjacent metavolcanic belt.

Within the metavolcanic belt are several late- to post-tectonic felsic intrusions that appear to possess primary magmatic foliations and stretching lineations formed during the emplacement of these bodies. The Ochig Lake Pluton, and Hooker-Burkoski Stock are quartz-phyric trondhjemite intrusions. The Pickle Lake Stock is similarly quartz-phyric but locally contains potassic-feldspar megacrysts. These three intrusions may be related as domical exposures of a common granitoid mass. Each of the three intrusions has imposed a strain fabric and a metamorphic aureole upon the surrounding supracrustal rocks. The Ochig Lake Pluton, for example, has produced a contact strain aureole up to 3 km wide on its eastern margin. The strain aureole surrounding the Pickle Lake Stock encompasses the Thierry Mine copper-nickel deposit, and an examination of that deposit suggests that the remobilization and concentration of sulphide mineralization is related to the deformation imposed by the emplacement of the Pickle Lake Stock (*see* Stott and Brown, this volume).

The Kasagiminnis Lake Pluton is a late, unmetamorphosed granodiorite intrusion that contains both quartz phenocrysts and potassium-feldspar megacrysts and is texturally similar to the Osnaburgh Pluton (Figure 002.1).

STRUCTURAL GEOLOGY

Reliable top indicators are not widespread in the northwestern half of the belt. However, stratigraphic younging evidence in the southeastern half of the belt, outside of the tightly folded rocks in the Pickle Crow area, suggests that the regional younging direction in this part of the belt is southeastwards towards the Seach-Achapi Lakes granitoid complex.

Mapping by Pye (1975) and earlier workers has defined large folds of the stratigraphy in the Pickle Crow area, and local younging evidence from pillowed basalts, confirm the earlier defined anticlines and synclines there (Pye 1975). However, in other parts of the belt, the continuity of electromagnetic conductors and stratigraphic units, such as ironstone and intermediate tuff, suggests a simple stratigraphy on the regional scale with megascopic folding concentrated locally, for example, south of the Ochig Lake Pluton.

Observed in most areas of the belt is a single planar alignment of minerals, a schistosity which lies at a small angle to or parallel to the bedding. There

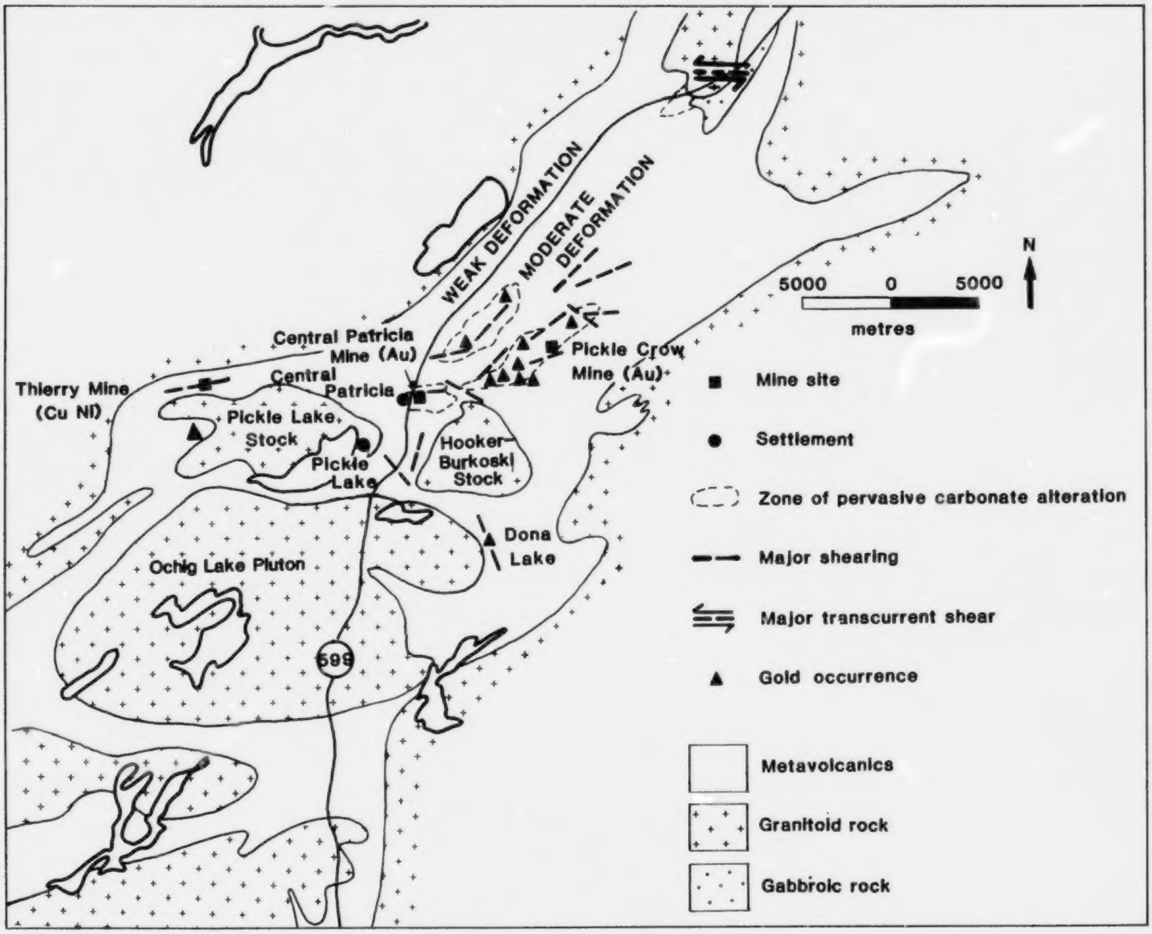

WEAK DEFORMATION
MODERATE DEFORMATION
Central Patricia Mine (Au)
Central Patricia
Thierry Mine (Cu Ni)
Pickle Lake Stock
Pickle Lake
Hooker-Burkoski Stock
Pickle Crow Mine (Au)
Dona Lake
Ochig Lake Pluton
599
N
5000 0 5000
metres
■ Mine site
● Settlement
Zone of pervasive carbonate alteration
Major shearing
Major transcurrent shear
▲ Gold occurrence
Metavolcanics
Granitoid rock
Gabbroic rock

Figure 002.2. *Structural domains in the Pickle Lake Belt.*

are regional variations in the intensity of development of this schistosity. A weak flattening fabric is typical of the northwesternmost part of the belt along Highway 808. A moderate deformation appears to be most typical of other parts of the belt with notable exceptions. These exceptions include:

1. discrete deformation zones of strong to intense schistosity in the Pickle Crow area
2. a triangular area of the belt south of Ochig Lake Pluton, squeezed between several late plutons and bearing a highly constrictive strain where rocks in many places are almost purely lineated
3. strong flattening fabrics in the supracrustal rocks enveloping the late to post-tectonic plutons within the belt

This latter example is well illustrated by the strongly flattened and banded amphibolite on the Thierry Mine Road along the northern margin of the Pickle Lake Stock.

Other zones of shear have been observed locally (Figure 003.2 of Stott and Brown, this volume) but in each case the full extent of these zones is not established. One example is an east-trending zone of right-handed transcurrent shear, several tens of metres wide, within quartz diorite at July Falls on Highway 808 at the northernmost end of the belt. The narrow ductile deformation zones within the supracrustal wedge between the Ochig Lake Pluton and the Hooker-Burkoski Stock are another example.

Apart from a late transcurrent shear zone seen at July Falls, where the stretching lineation is subhorizontal, most zones of strong to intense deformation show moderate to steeply plunging lineations which conform to the stretching lineations in the surrounding moderately deformed rocks. In spite of the generally poor bedrock exposure which characterizes large parts of the Pickle Lake Belt, there are regional patterns of total strain in the rocks which allow for subdivision of the belt into structural domains (Figure 002.2). These domains are defined mainly by orientations of stretching lineations and fold axes (all lineations referred to below are stretching lineations).

In general, the oldest observed strain element in the belt appears to be an easterly to north-northeasterly plunging stretching lineation which characterizes most of the northern and eastern parts of the belt (Figure 002.2). This region, termed Domain 1, is mainly flanked to the southeast by the tonalite terrain of the Seach-Achapi Lakes granitoid complex. Domain 1 includes the Pickle Crow area and mineralized deformation zones. The gold-quartz veins in these deformation zones are folded and typically possess steep northeasterly plunging lineations. Stott and Brown (this volume) suggest that this gold mineralization is localized along discrete shear zones, some of which are folded, formed at a low angle to the flattening schistosity, and concomitant with the deformation that characterizes this domain.

Northeast of Domain 1 is Domain 2 characterized by westerly plunging lineations that parallel lineations in the adjacent quartz-phyric Croshaw Lake Pluton (Figure 002.2). It is suggested here that Domain 2 may represent a wide contact strain aureole related to the emplacement of the Croshaw Lake Pluton and postdating the strain event recorded in Domain 1.

Other recognizable domains (Domain 3 in Figure 002.2) are spatially restricted contact strain aureoles surrounding, or adjacent to late felsic plutons such as the Pickle Lake Stock and the Ochig Lake Pluton.

The earliest stages of the tectonic history remain a mystery but some features of the overall history are suggested from this reconnaissance study. The first two points are largely speculative at present.

1. If there was a regional tilting of strata towards the southeast, it probably predated the emplacement of tonalite in the Seach-Achapi Lakes granitoid complex. Such a southeastward tilting may correspond to the southward-facing homoclinal tilt of stratigraphy that forms the Meen-Dempster Lakes Belt, west of Kasagiminnis Lake (Stott and Wilson 1986). This megascopic tilting of the supracrustal rocks may extend beyond the length of any individual batholith and as such, may be attributable to an early orogenic force of a much broader scale.
2. A record of the deformation in structural Domain 1 can be seen in the steep northeast-plunging lineations and fold axes in bedding and quartz veins at the former settlement of Pickle Crow, related possibly to the emplacement of tonalite in the Seach-Achapi Lakes granitoid complex. Domain 1 may have covered a broader region prior to the emplacement of the Croshaw Lake Pluton and the younger post-tectonic intrusions. Local sets of shear zones and fractures developed at a low angle to the flattening schistosity. This is most evident in the Pickle Crow area where these narrow shear zones host gold-bearing quartz veins.
3. Development of structural Domain 2 was concomitant with the emplacement of the Croshaw Lake Pluton. Domain 2 within the belt outlines an area with a westerly plunging mineral lineation which corresponds to the lineation observed in the Croshaw Lake Pluton. Field relationships show that this pluton postdates the tonalitic terrain along its southern flank.
4. The emplacement of late- to post-tectonic felsic plutons has imposed contact strain aureoles (Domain 3) and metamorphic aureoles upon the adjacent supracrustal rocks. In some cases, narrow shear zones have developed within these aureoles. Examples occur between the Ochig Lake Pluton and the Hooker-Burkoski Stock and on the northern side of the Pickle Lake Stock, at the Thierry Mine. Another possible example are shear zones, not exposed on surface, at the Dona Lake gold deposit (Cohoon 1986).
5. Late transcurrent shear zones may predate or postdate the late felsic intrusions. The transcurrent shear zones, such as the east-trending right-handed shear zone at July Falls, are interpreted to be related to the same late stage of crustal shortening that produced the Lake St. Joseph Fault at the Uchi-English River Subprovinces boundary (Stott 1985) and the shear zone along the northeastern boundary of the Meen-Dempster Lakes Belt (Stott and Wilson 1986).

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003. Economic Geology of the Pickle Lake Metavolcanic Belt, District of Kenora, Patricia Portion

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INTRODUCTION

A preliminary evaluation of the economic geology of the Pickle Lake Metavolcanic Belt was made during a 1:50 000 scale mapping survey of this greenstone belt (*see* Stott, this volume). Partial funding for this aspect of the project was provided by the Resident Geologist's Office, Ontario Ministry of Northern Development and Mines, Sioux Lookout. The work consisted of:

1. assay sampling in areas outside of known gold occurrences
2. reconstructing the structural framework of some gold occurrences
3. assessing regional deformation patterns and their potential relationship to gold mineralization

PREVIOUS WORK

Since 1928, the Pickle Lake area has experienced fluctuating periods of activity in gold exploration, base-metal exploration, and more recently in a renewed effort to find new gold deposits. The outcome of almost 60 years of activity has been the development of two gold mines (both long since closed (the Pickle Crow Mine (Thomson 1939; Corking 1948) and the Central Patricia Mine (Barrett and Johnston 1948)), the development of a low grade copper-nickel deposit at the Thierry Mine (also closed) (Verbeek *et al.* 1972; Patterson 1980), and the recent discovery of the Dona Lake gold deposit southeast of the Town of Pickle Lake (Cohoon 1986). There is also renewed interest in the vein systems at the Pickle Crow Mine held by Highland Crow Resources Limited.

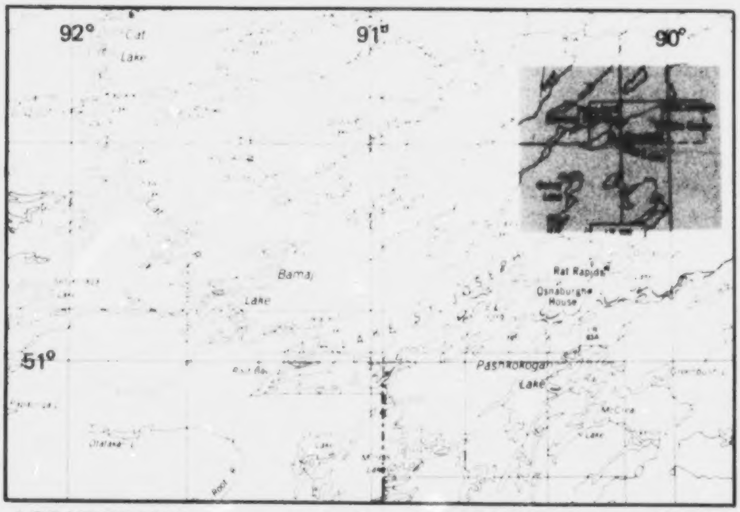
Figure 003.1 illustrates that much of the belt has been staked in recent years, reflecting the intensity of interest that has been generated about the potential for more gold deposits across much of the central Uchi Subprovince.

GOLD

Exploration for gold in the Pickle Lake Belt has focused for many years on ironstone units. This arose from the fact that gold-bearing stockworks of quartz- and sulphide-filled fractures occur in ironstones at both the Central Patricia Mine (Barrett and Johnston 1948) and in parts of the Pickle Crow Mine (Thomson 1939). In addition, sulphidized zones occur where shear zone-hosted quartz veins intersect ironstone beds (for example, number 5 vein at the Pickle Crow Mine). Ironstone beds served as effective structural traps for hydrothermal fluids and, of equal importance, as chemical traps wherein replacement sulphide mineralization was produced and accompanying gold in solution was preferentially precipitated (Macdonald 1984). The importance of searching for sulphidized parts of ironstones is underlined by the discovery in 1984 of the Dona Lake Gold Deposit (Figure 003.1) by Dome Exploration (Canada) Limited.

However, there are also important regional structural relationships that should be considered (apart from identifying fold hinges) in planning an exploration program for gold. It is important to identify those areas with a greater likelihood to contain zones of intense deformation that could have served as permeable conduits for the flow of hydrothermal fluids.

Figure 002.2 of Stott (this volume) illustrates that the Pickle Lake Belt can be subdivided into several



LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

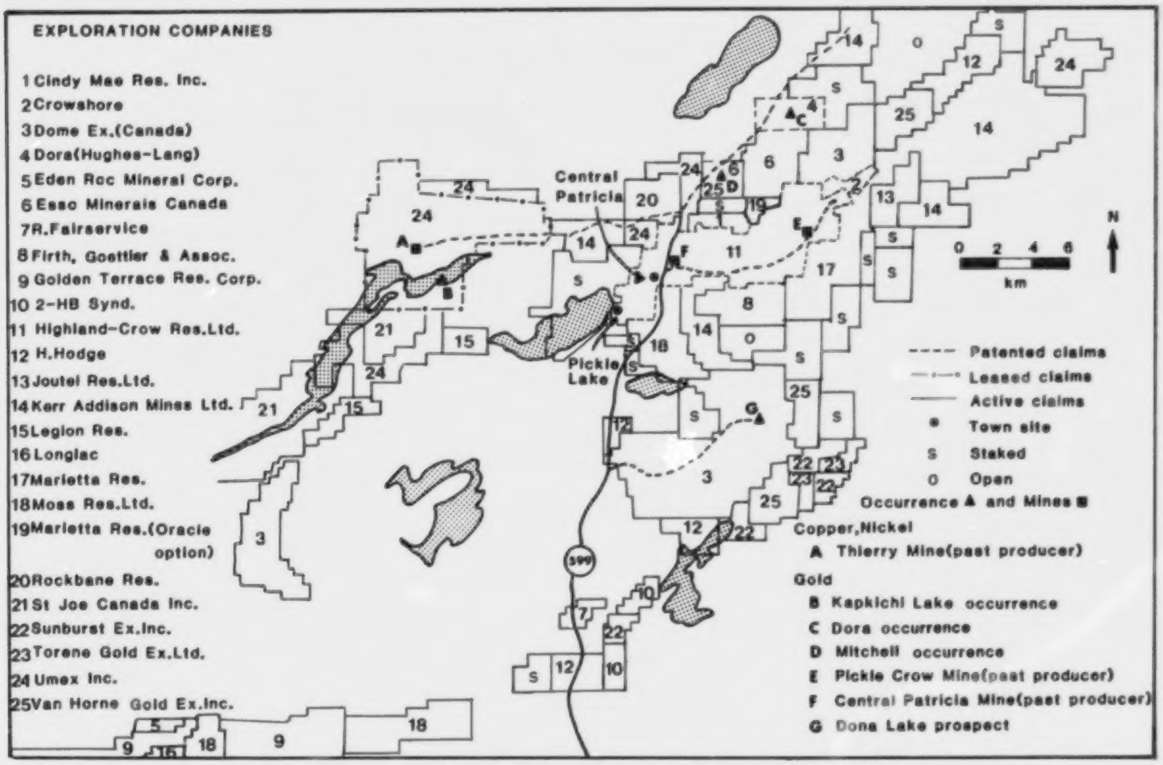

EXPLORATION COMPANIES
1 Cindy Mae Res. Inc.
2 Crowshore
3 Dome Ex.(Canada)
4 Dora(Hughes-Lang)
5 Eden Roc Mineral Corp.
6 Esso Minerals Canada
7 R.Fairservice
8 Firth, Goettler & Assoc.
9 Golden Terrace Res. Corp.
10 2-HB Synd.
11 Highland-Crow Res.Ltd.
12 H.Hodge
13 Joutel Res.Ltd.
14 Kerr Addison Mines Ltd.
15 Legion Res.
16 Longlac
17 Marietta Res.
18 Moss Res.Ltd.
19 Marietta Res.(Oracle option)
20 Rockbane Res.
21 St Joe Canada Inc.
22 Sunburst Ex.Inc.
23 Torene Gold Ex.Ltd.
24 Umex Inc.
25 Van Horne Gold Ex.Inc.
Central Patricia
Pickle Lake
599
0 2 4 6
km
N
Patented claims
Leased claims
Active claims
Town site
S Staked
O Open
Occurrence ▲ and Mines ■
Copper,Nickel
A Thierry Mine(past producer)
Gold
B Kapkichi Lake occurrence
C Dora occurrence
D Mitchell occurrence
E Pickle Crow Mine(past producer)
F Central Patricia Mine(past producer)
G Dona Lake prospect

Figure 003.1. Location of both active and patented claims in the Pickle Lake area (May 1986).

structural domains. Major parts of the belt are dominated by contact strain aureoles imposed by the emplacement of late tectonic intrusions. Experience in other greenstone belts (Stott and Wilson 1986) suggests that although there is a general decrease in the intensity of deformation outwards from these plutons, considerable variations in strain intensity can occur within these aureoles and that localized shear zones, as well as tight folds and fracture systems, commonly form as part of such deformation. Zones of intensely developed schistosity can occur adjacent to or within comparatively more competent lithologies, such as porphyry intrusions and banded ironstones, and comparatively less competent lithologies, such as intermediate tuff units. It is not generally possible to predict whether and where such zones will develop within contact strain aureoles. Their association, however, with the rise of granitoid intrusions means that the recognition of the relative timing of the intrusions and the breadth of their surrounding contact strain aureoles is economically important.

The authors recognize three types of shear zones within the strain aureoles of felsic intrusions:

1. a single shear zone at the outboard margin of a broad contact strain aureole produced by a large batholith. An example in the Meen-Dempster Lakes Belt (Stott and Wilson 1986) is the shear zone that lies at the southern margin of the strain domain adjacent to the Dobie Lake Batholith, west of the Pickle Lake Belt. This zone is interpreted as a zone of differential displacement between the subsiding and flattened domain of contact strain and the unaffected supracrustals that lie south of this domain and away from the batholith. Gold-bearing quartz-tourmaline veins in this zone form over-rotated infillings of tension gashes developed during the shearing.
2. stratigraphically-controlled shear zones developed within or along the margins of certain lithologies, notably banded ironstone. One example is the narrow shear zone, at the Dona Lake Gold Deposit, which extends for over 1 km along the footwall margin of the ore-bearing ironstone (Cohoon 1986). This zone lies within the 3 km wide contact strain aureole imposed upon the supracrustal rocks by the Ochig Lake Pluton. The strain aureole is shown schematically in Figure 003.2 of Stott, this volume.
3. shear zones formed along conjugate fractures at a low angle (typically 15°) to the principal flattening schistosity. Very locally, both members of a conjugate set may form as narrow shears, but in general only one member of the set appears to develop into a significant shear zone in any one locality. This appears to be the case at the Pickle Crow Mine. Many of the major shear zones that host auriferous quartz, tourmaline, and sulphide mineralization veins are slightly oblique to the main northeast-striking flattening schistosity in

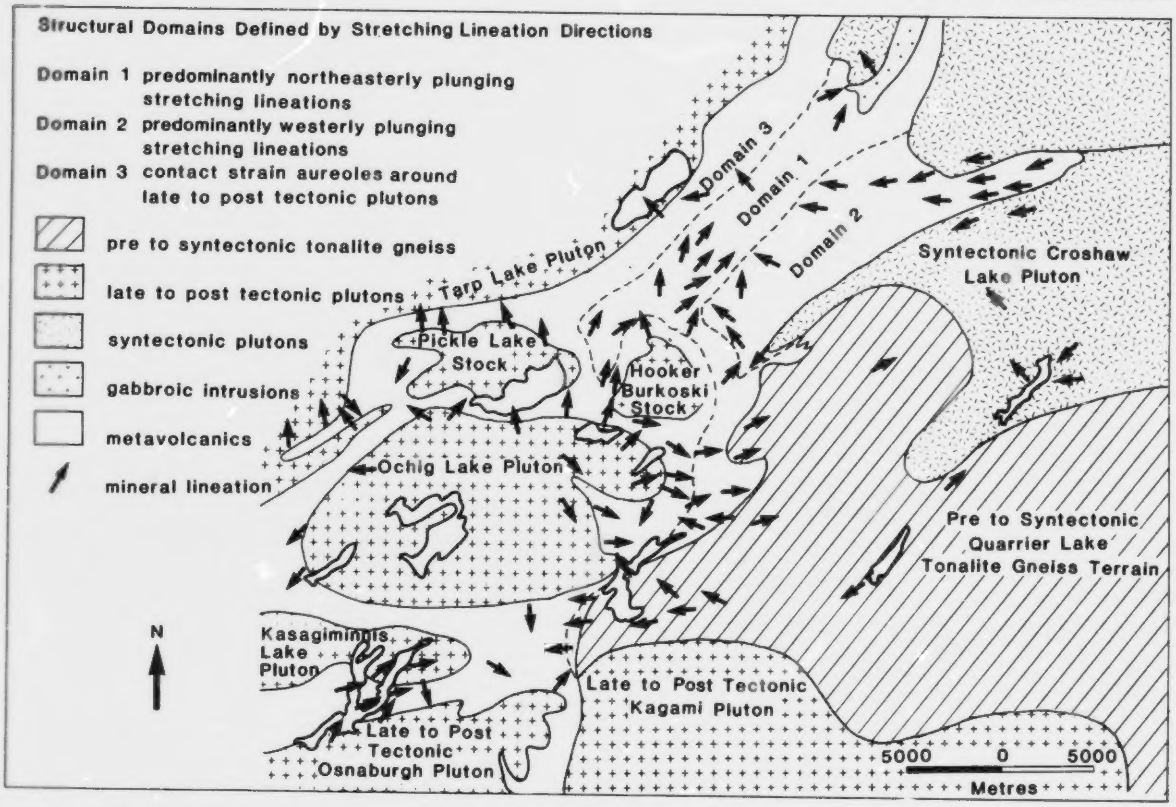

Structural Domains Defined by Stretching Lineation Directions
Domain 1 predominantly northeasterly plunging stretching lineations
Domain 2 predominantly westerly plunging stretching lineations
Domain 3 contact strain aureoles around late to post tectonic plutons
pre to syntectonic tonalite gneiss
late to post tectonic plutons
syntectonic plutons
gabbroic intrusions
metavolcanics
mineral lineation
Domain 3
Domain 1
Domain 2
Tarp Lake Pluton
Syntectonic Croshaw Lake Pluton
Pickle Lake Stock
Hooker Burkoski Stock
Ochig Lake Pluton
Pre to Syntectonic Quarrier Lake Tonalite Gneiss Terrain
N
Kasagiminnis Lake Pluton
Late to Post Tectonic Kagami Pluton
Late to Post Tectonic Osnaburgh Pluton
5000 0 5000
Metres

Figure 003.2. *Shear zones and zones of carbonate alteration in the Pickle Lake Belt.*

this structural domain (Domain 1 in Figure 003.2, Stott, this volume). These zones, in many cases, are folded and in all cases they contain asymmetrically folded quartz veins. The asymmetry of folds in these cases is consistent with conjugate fracturing, shearing, and concomitant rotation towards the flattening plane during a major shortening event that produced the Domain 1 schistosity and stretching lineations.

Very similar observations have been made by Wilson *et al.* (1985) across the Red Lake Belt. They recognize conjugate fractures and shear zones as structural elements formed during subhorizontal flattening of the supracrustal rocks by adjacent plutons. The principal shear zones and vein systems at the Pickle Crow Mine including the Howell vein, the Riopelle, and No. 5 veins and the "D" zone (Pye 1976, p.171) conform to a model of conjugate fracturing during northwestward-directed shortening of the supracrustals. This apparently occurred during expansion of the tonalitic mass to the southeast of the belt in the Seach-Achapi Lakes granitoid complex. It may eventually be shown with further study that these auriferous conjugate shear zones, so well developed in the Pickle Crow area, are related to the pervasive iron carbonatization in this area at the time of deformation (Figure 003.2). For similar observations in the Red Lake Belt *see* Andrews (1984).

In addition to these three types of shear zones that are associated with plutonic emplacement, we also distinguish major transcurrent shear zones that tend to form along northwest-trending granite-greenstone boundaries as well as along subprovince boundaries. These transcurrent shear zones are related to a major late stage, northwest-directed, oblique compression of the crust. One example is the transcurrent shear zone along the northeastern margin of the Meen-Dempster Lakes Greenstone Belt (Stott and Wilson 1986). There appear to be several splays off this zone including one which is localized within and along the margins of a narrow felsic tuff unit at the St. Joe Canada Incorporated gold discovery north of Muskegsagagen Lake, 65 km southwest of the Town of Pickle Lake. An auriferous cherty quartz sheet several thousand metres long occurs along the margin of this unit (The Northern Miner, 1986).

With an understanding of the structural significance of both late-tectonic felsic plutons and late stage subhorizontal oblique compression of the crust, the different structural settings of gold deposits can be assessed and these deposits can be placed in the relative sequence of regional tectonic events. For example, there are differences in the regional structural settings between the Dona Lake Deposit (Figure 003.2) and deposits at the Pickle Crow Mine. The authors' work has indicated that the contact strain aureole and amphibolite facies metamorphism imposed by the Ochig Lake Pluton (Figure 002.2, Stott, this volume) encompasses the ironstone units on its eastern margin. The major penetrative fabric imposed by the pluton is superimposed by later structures, in particular steeply plunging flexures or "cross folds" (Cohoon 1986) of the schistosity and bedding. Field evidence suggests that the open flexure folding of the bedding is restricted to the supracrustal rocks at the eastern margin of the pluton. Since the emplacement of the Ochig Lake Pluton is the last deforming event in the vicinity of the gold deposit, it is reasonable to suggest that a progressive history of diapirism, ballooning, and second-order doming of the intrusion is responsible for the sequence of structures observed along the length of the supracrustal "tail" leading northward to the gold deposit. The Dona Lake Deposit is therefore interpreted to accompany the emplacement of the Ochig Lake Pluton.

However, in contrast, the vein systems in the variably iron carbonatized rocks of the Pickle Crow area are related to an earlier deformational event that formed the structures of Domain 1 (Figure 002.2, Stott, this volume). Discrete shear zones carry gold in quartz veins that transect a range of host lithologies. The significance of the orientation of these shear zones was discussed earlier. They appear to be synkinematic with the development of the main penetrative schistosity in Domain 1. This schistosity was deflected and locally buckled by the emplacement of the trondhjemitic Hooker-Burkoski Stock which appears to be magmatically related to the Ochig Lake Pluton.

The implication, therefore, is that the mineralization in the area of Pickle Crow and Central Patricia was emplaced during a deformational event (possibly related to emplacement of tonalitic rocks southeast of the belt) which preceded the emplacement of the Hooker-Burkoski and Ochig Lake intrusions and accordingly, preceded the emplacement of the Dona Lake Gold Deposit.

THE THIERRY MINE COPPER-NICKEL DEPOSIT

The Thierry Mine is located just north of the Pickle Lake Stock (Figure 003.2) and lies within a contact strain aureole imposed by the stock (Figure 002.2, Stott, this volume).

The mine has a history of almost 10 years as a producer of low grade copper and nickel before closing down in 1982. The mine consists of underground workings and two open pits within sheared gabbroic rocks and ultramafic schists. The ore principally contains chalcopyrite, pyrrhotite, pyrite, and pentlandite and forms several structural types including breccia ore, chlorite-biotite schist ore, and ores of disseminated sulphide mineralization (Patterson 1980).

The authors examined this deposit underground at the 850-foot level and on the surface in the East Pit. There is a consistent northward dip of schistosity in the amphibolites and a downdip to moderately northwest-plunging mineral lineation. Associated with this penetrative ductile fabric are discrete normal faults and fractures, subparallel to schistosity, plus narrow shears along fault planes with identical mineral lineation orientation. The sense of movement on these fault surfaces, and on the penetrative foliation surfaces, is best observed on the southern wall of the East Pit. Numerous penetrative step fractures, local penetrative rotation of flattening schistosity into shear cleavages, and slickensides on fault planes indicate that a south-side up sense of movement (i.e. pluton-side up) is pervasive. This sense of movement is consistent across the breadth of the Thierry Mine Property.

The northward dip of schistosity away from the Pickle Lake Stock, the sense of movement on the penetrative schistosity and fault planes, the intense colour banding and higher metamorphic grade (amphibolite facies traced around the pluton), plus the width of the contact strain aureole strongly suggest that the sulphide mineral emplacement as massive fracture fillings (some containing brecciated amphibolite) and disseminations to form ore occurred during the emplacement of the Pickle Lake Stock. The authors suggest, therefore, that the structural framework of the deposit may be intimately related to the emplacement of the Pickle Lake Stock.

The authors also note, on the southern wall of the East Pit, the presence of sulphide mineral-bearing cherty quartz veins that cut the above-mentioned fabrics. These veins appear to be spatially related to a late set of steep listric reverse faults that show south-side up sense of movement. The faults are well exposed on the southern and western walls of the East Pit. They may reflect more brittle responses to the same pluton-induced stress system.

PROSPECTING RECOMMENDATIONS

The following recommendations are both specific to the Pickle Lake Belt and generally applicable elsewhere in the Uchi Subprovince.

1. It is recommended that prospectors focus on discrete zones of strong to intense deformation within broad contact strain aureoles around late felsic plutons, especially where structural and chemical traps are present. The recognition of these strain aureoles is therefore the first step. Not all late intrusions have imposed broad strain domains, but there is an abundance of these late intrusions in the Superior Province and many appear to cluster in age (Colvine *et al.* 1985).
2. It is also recommended that consideration be given to tracing late transcurrent faults and shear zones. Most have probably formed along greenstone-granite boundaries and subprovince boundaries but some east-trending faults may also transect significant portions of a greenstone belt. They formed by northwest directed oblique compression of the crust and postdate other tectonic events. One possible example is the east-trending transcurrent shear zone at the northeastern end of the Pickle Lake Metavolcanic Belt (Figure 003.2). This zone may be accompanied by others not yet identified within the belt.

   Splays off faults or shear zones along greenstone-granite boundaries may locally project into a greenstone belt and trace along bedding surfaces for some distance. Such shear systems in greenstone belts are similar to wrench faults (Wilcox *et al.* 1973) but modified and controlled by prominent planar anisotropies in the supracrustal rocks. The transcurrent shear zone along the northeastern margin of the Meen-Dempster Lakes Belt (Stott and Wilson 1986) is an example. It is broadest in the vicinity of the stratigraphically-controlled St. Joe Canada Incorporated gold discovery north of Muskegsagagen Lake. Similar deformation zones can be predicted and sought along similar northwest and northeast-trending greenstone-granite boundaries; for example, the Keezhik Lake Belt north of Miminiska Lake in the eastern Uchi Subprovince bears a marked similarity in form and orientation to the Meen-Dempster Lake Belt. In addition, "horsetail" splays off of major subprovince boundary faults have not all been identified and some of these may have produced important structural traps within greenstone belts.

3. Finally, in view of current interest in gabbroid-related platinum group mineralization, we recommend that some investigation be made of the Kibler Lake Stock (Figure 002.1, Stott, this volume) since it may be a zoned mafic intrusion (Stott, this volume; Sage and Breaks 1982, p.193). Little is known about this body which is not exposed on the surface.

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004. Geology of the Northwestern Birch Lake Area, District of Kenora (Patricia Portion)

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[2]Graduate Student, University of Western Ontario, London.

INTRODUCTION

Field work done in 1986 represents the second year of a multiyear program of detailed and synoptic mapping in the Birch Lake Greenstone Belt, Uchi Subprovince. The 1986 map area is bounded by Latitudes 51°22′50″N and 51°27′10″N and Longitudes 92°39′26″W and 92°22′00″W and covers an area of approximately 170 km². This project, and that currently underway in the area immediately to the east (*see* Good, this volume), completes the first phase of a multiyear detailed mapping program focusing on the geology and mineral potential of the Birch Lake Belt. The Town of Red Lake is located about 100 km west-southwest of the map area. Access to the area is by float plane from Red Lake.

MINERAL EXPLORATION

The information on exploration activity summarized below is taken from previous reports on the area (Furse 1934; Harding 1936; Thurston 1986) and the Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Red Lake.

The discovery of gold at Red Lake in 1926 precipitated approximately 10 years of extensive prospecting activity in the Birch Lake area. This prospecting led to the discovery of numerous showings and several mines outside of the immediate map area (Furse 1934; Harding 1936; Thurston 1986).

Interest in the base-metal potential of the area was sparked by the discovery of the South Bay copper-zinc Deposit in 1968. Between 1968 and 1972, several airborne geophysical surveys were conducted and anomalies were examined by ground geophysics, prospecting, trenching, and diamond drilling. Follow-up work to these surveys in the 1986 map area was restricted to the southeastern part where diamond drilling revealed only minor sulphide mineralization. Evaluation of molybdenum mineralization in the southern part of the Mink Lake Stock (northern part of map area) was also carried out at this time.

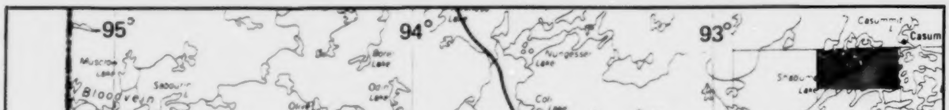
Recent mineral exploration has concentrated on the gold potential of the area.

GENERAL GEOLOGY

All of the bedrock in the area is inferred to be of late Archean age. Thurston (1986) has tentatively correlated various sequences around Birch Lake with the volcanic cycles recognized in the Confederation Lake area to the south, where volcanism is known to range in age from 2960 to 2740 Ma (Nunes and Thurston 1980).

Supracrustal and high level intrusive rocks of the Birch-Uchi Greenstone Belt underlie most of the area, the exception being the western part of the map area which is underlain by granitoid rock of a large batholithic complex. The area has been mapped previously on reconnaissance scales by Harding (1936), Goodwin (1967), Thurston *et al.* (1981), and Thurston (1986).

Mafic, intermediate, and felsic metavolcanics are all well represented within the map area. Many of the units can be correlated with those lying northwest of the Swain Lake Deformation Zone (SLDZ) in the area to the south (Beakhouse 1985). Interpretation of stratigraphic relationships is hampered by the presence of deformation zones and/or faults having un-


95°
94°
93°
51°
MANITOBA
Muscrow Lake
Bloodvein
Sabourin L
Larus Lake
River
Murdoch Lake
Carroll Lake
Donald L
Haggart L
Eagle L
Sydney Lake
Confusion L
Telescope L
Olive Lake
Odin Lake
Bow Lake
Chukuni
Little Vermilion Lake
Nungesser Lake
Coli Lake
Trout Lake
EL 1294
Joyce Lake
Little Trout Lake
Pipestone
Indian House Lake
Bay
Ball
Todd
RED LAKE
Graves
Mc Donough
Bateman
Shaver
Fairlie
McKenzie I
Balmer
Ranger Lake
Ranger
Mulcahy
Killala
Baird
Heyson
Madsen
Byshe
Willans
Upper Medicine Stone Lake
Longlegged Lake
Snake Falls
Pakwash Lake
Trout Lake
Bruce Lake
Wenasaga L
Ear Falls
Goldpines
RIVER
Bluffy
Aerofoil L
Wapesi
Casummit L
Casummit
Shabumeni Lake
Swain Post
Gunner Narrow Lake
Goodall
Honeywell
Mc Naughton
Costello
Corless
Jackson Manion
Agnew
Perrigo
Knott
Mitchell
Birkett
Uchi Lake
Belanger
Bowerman
Slate Lake
Papaonga R
Wenasaga

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

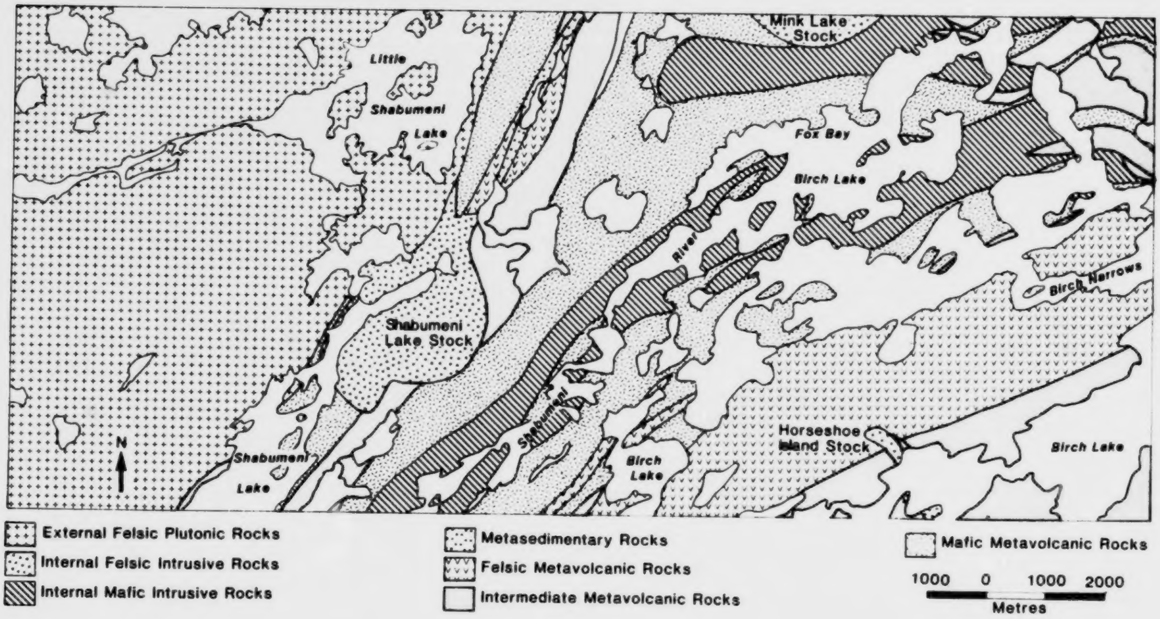

Mink Lake Stock
Little Shabumeni Lake
Fox Bay
Birch Lake
River
Birch Narrows
Shabumeni Lake Stock
Shabumeni
Horseshoe Island Stock
Birch Lake
Birch Lake
N
Shabumeni Lake
External Felsic Plutonic Rocks
Internal Felsic Intrusive Rocks
Internal Mafic Intrusive Rocks
Metasedimentary Rocks
Felsic Metavolcanic Rocks
Intermediate Metavolcanic Rocks
Mafic Metavolcanic Rocks
1000 0 1000 2000
Metres

Figure 004.1. *Generalized geology of the northwestern Birch Lake area.*

known displacement along several of the principal lithological contacts.

Mafic metavolcanics, hereafter referred to as the Fox Bay basalts, underlie a large area centred on Fox Bay (Figure 004.1), where they have been folded about a regional syncline (Figure 004.2). The exposed stratigraphic thickness of the Fox Bay basalts is approximately 2500 m. Both massive and pillowed flows are well represented. Distinctive porphyritic flow units, with subhedral to subrounded plagioclase phenocrysts up to 6 cm in diameter, are conspicuous locally. Medium-grained metabasalt and metagabbro are abundant in the upper portion of this unit. This mafic unit interfingers with intermediate metavolcanics to the southwest (Beakhouse 1985) and east.

A relatively thin (maximum thickness 750 m) unit of equigranular, massive mafic metavolcanic with subordinate pillowed flows lies adjacent to the batholithic complex in the western part of the area. This unit is amphibolitic within 200 to 400 m of the contact with the batholith.

Intermediate metavolcanics occur in several parts of the map area (Figure 004.1):

1. In the southeastern part of the map area, massive to moderately well-bedded, tuff, lapilli-tuff and tuff-breccia are associated with minor massive flows.
2. In the northeastern part of the map area, well-bedded tuff, feldspar crystal tuff, and associated volcaniclastic metasediments, together with subordinate lapilli-tuff and tuff breccia, interfinger with the thick mafic sequence (Fox Bay basalts) centred on Fox Bay.
3. A northeast-trending unit, lying between the Shabumeni River and Shabumeni Lake, consists of lapilli-tuff and tuff-breccia with subordinate amounts of tuff. In general, bedding is less well developed in this unit as compared to those discussed above, although several thin sedimentary (possibly volcaniclastic) intercalations within the unit display very thin, even, and continuous bedding.
4. Massive to crudely bedded feldspar crystal tuffs outcrop on the western shore of Shabumeni Lake in the southwestern part of the map area.

Even though these intermediate sequences display differences in the proportion of lithologies and primary structures, they are broadly similar in certain respects. Feldspar phenocrysts and crystal fragments are abundant in all intermediate sequences in the map area. Lapilli-tuffs and tuff-breccias are dominantly heterolithic; clast types commonly include a range of textural varieties of intermediate volcanic rocks together with minor mafic and felsic volcanic and chemical sedimentary clasts. Clasts are generally well rounded, suggesting some degree of reworking. No evidence for a proximal depositional facies of intermediate volcanism was noted in the map area.

The most areally extensive felsic metavolcanic unit in the map area occurs on the large peninsula in the southeastern part of the map area. Massive and flow-banded flows and flow breccia predominate with lesser amounts of coarse to fine pyroclastic deposits. Fragmental units are dominantly monolithic with clast shape ranging from subrounded to angular. The unit is interpreted to be a rhyolite dome, with flanking fragmental deposits, representing the vent and proximal facies (Easton and Johns 1986) of a felsic volcanic centre.

Smaller felsic pyroclastic units occur in the south-central part of the map area and between Fox Bay and Little Shabumeni Lake.

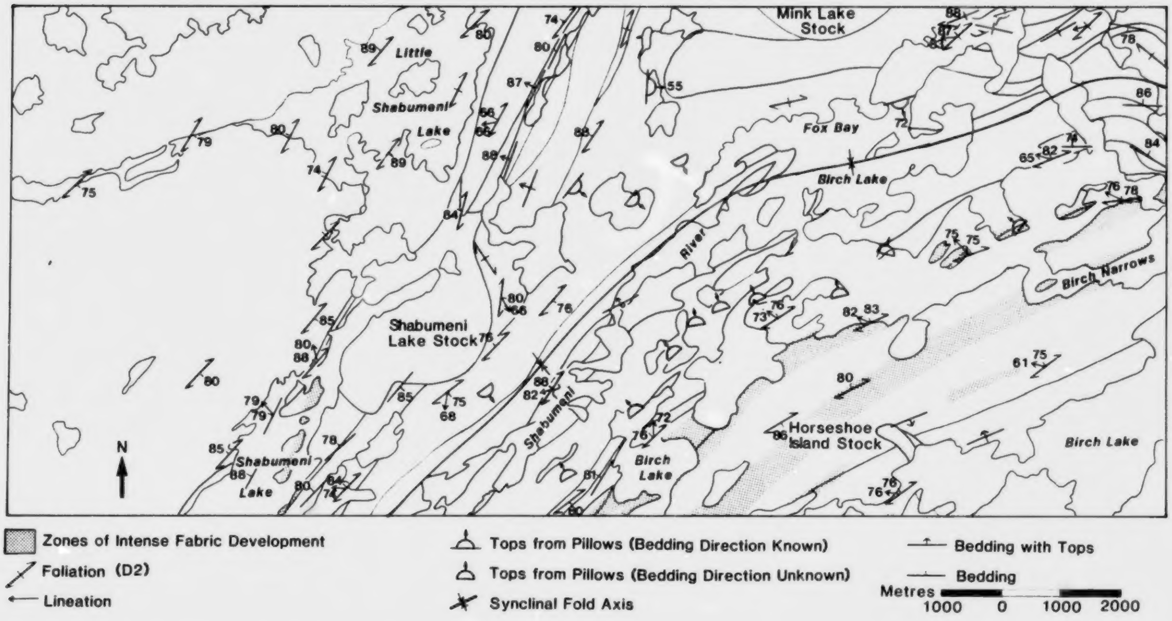

Mink Lake Stock
Little Shabumeni Lake
Fox Bay
Birch Lake
River
Birch Narrows
Shabumeni Lake Stock
Shabumeni
Horseshoe Island Stock
Birch Lake
Shabumeni Lake
Birch Lake
N
Zones of Intense Fabric Development
Foliation (D2)
Lineation
Tops from Pillows (Bedding Direction Known)
Tops from Pillows (Bedding Direction Unknown)
Synclinal Fold Axis
Bedding with Tops
Bedding
Metres
1000 0 1000 2000

Figure 004.2. *Structure of the northwestern Birch Lake area.*

Metasediments, although not abundant, are widespread as thin units intercalated with metavolcanics and include both clastic (wacke-siltstone) and chemical (chert-magnetite) varieties. The only metasedimentary unit of sufficient extent to be shown on the accompanying map (Figure 004.1) occurs east of Little Shabumeni Lake and consists of evenly bedded, thinly bedded to laminated, often graded, wacke-siltstone. Similar lithologies occur as thin intercalations within metavolcanics south of the Shabumeni Lake Stock and along the Shabumeni River. In the latter case, the clastic metasediments are associated with chert and magnetite beds.

Three categories of intrusive rocks are recognized in the map area; mafic intrusions, high level felsic intrusions within the greenstone belt, and a plutonic complex lying to the west of the greenstone belt.

Mafic intrusions are predominantly gabbroic in composition and are commonly associated with mafic metavolcanics. These metagabbros are especially abundant along the Shabumeni River and north and east of Fox Bay. A noteworthy example of a gabbro not associated with mafic metavolcanics is located adjacent to the Horseshoe Island Stock (Figure 004.1) and carries minor nickel sulphide mineralization.

Three major high level felsic intrusions occur within the map area; the Mink Lake Stock in the northern part of the map area, the Horseshoe Island Stock in the southeast, and the Shabumeni Lake Stock in the west.

The Mink Lake Stock is largely granodioritic in composition, contains equigranular and porphyritic (quartz) phases, and has associated molybdenum mineralization. The Horseshoe Island Stock is a finer grained, equigranular granodiorite. Gold mineralization has been outlined within, and marginal to, the Horseshoe Island Stock (Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Red Lake). The Shabumeni Lake Stock has previously been grouped with the granitoid complex lying to the west (Thurston *et al.* 1981), but detailed mapping has shown it to be similar in many respects to the Mink Lake Stock. It contains porphyritic (quartz) granodioritic, quartz monzodioritic, and monzonitic phases. Numerous, small, intermediate to felsic dikes also occur throughout the greenstone belt.

The external granitoid complex consists largely of microcline megacrystic hornblende±biotite granodiorite. The outer 1000 m of this complex shows an eastward decrease in quartz content and increase in colour index. Rocks immediately adjacent to the metavolcanics are hornblende quartz monzodiorites.

STRUCTURE

In the western part of the map area, steeply dipping supracrustal rocks strike northeast, parallel to the greenstone belt-granitoid complex contact. In the eastern part of the map area bedding is more irregular, but has a general easterly trend. A mineral foliation (D_2) is parallel or slightly discordant to bedding throughout the map area.

The thick metabasalt-gabbro sequence centred on Fox Bay (Fox Bay basalts) is folded in a syncline, the axial trace of which lies along or slightly north of the Shabumeni River (Figure 004.2). In the heterolithic sequence northwest of the Fox Bay basalts, the sparse top indicators (graded bedding and scour principally in the metasedimentary unit) indicate younging to the northwest. Further work is needed to determine if the opposing facing between this sequence and the northwestern limb of the fold in the Fox Bay basalts reflects the presence of an anticlinal fold or a fault coincident with one of the unit contacts. The stratigraphic relationship of the Fox Bay basalts to the felsic metavolcanic unit in the southeastern part of the map area is also uncertain as a major deformation zone of unknown displacement occurs at the contact.

The Swain Lake deformation zone (SLDZ), recognized in the area to the south (Beakhouse 1985), can be traced into the map area as a series of splays which lie within and along the northern and southern contacts of the large felsic metavolcanic unit in the southeastern part of the map area. The splays are delineated on the basis of intense fabric development and are commonly associated with intense alteration (hydration and carbonatization). A consistent, strong, steep (70° to 80°), west- to northwest-plunging lineation occurs within the SLDZ and lineations with similar orientations occur within the metavolcanics and marginal parts of the external granitoid complex to the northwest of the SLDZ. This observation suggests that emplacement of the batholithic complex may have produced the intense fabric development in the SLDZ and the regional fabric in the intervening metavolcanics. The SLDZ contains little evidence for simple shear and the intense fabric development is interpreted to be largely due to pure shear. The limited evidence for simple shear consists of sigmoidal fabrics and step fractures which suggest that the northwestern side has moved up relative to the southeastern side with a minor dextral transcurrent component. The possibility that significant displacement occurred along narrow faults within these zones cannot be ruled out.

In the eastern part of the map area, three folding and/or flattening "events" can be distinguished. A rarely preserved, early flattening fabric (D_1) with a general north orientation is buckled by the D_2 deformation which gave rise to the regional (east-trending in this area) foliation and intense fabric development in the SLDZ. In the extreme northeastern part of the map area, the D_2 fabric is deformed into open folds with an axial surface and foliation (D_3) oriented approximately north. It is not clear if this multiplicity of deformation "events" reflects discrete episodes of deformation or a single, complex deformation. Both the D_2 and D_3 deformations are provisionally interpreted to be a consequence of emplacement of the external granitoid complexes; the origin of the D_1 structure is unknown.

ECONOMIC GEOLOGY

The map area has potential for the discovery of base-metal massive sulphide, disseminated molybdenum, and gold deposits. The most favourable environment for base-metal massive sulphide deposits is the large felsic unit in the southeastern part of the map area. This unit is identical in age to the mineralized cycle III metavolcanics at Confederation Lake (Thurston 1986) and the preponderance of rhyolite flows and coarse breccias suggests a vent to proximal facies which is empirically associated with volcanogenic massive sulphide deposits (Easton and Johns 1986).

Known disseminated molybdenum mineralization is restricted to the Mink Lake Stock. Future exploration for such deposits should concentrate on the Mink and Shabumeni Lake Stocks.

The most favourable environments for gold mineralization are zones of alteration, veining, and disseminated sulphide mineralization associated with zones of strong fabric development and areas within and marginal to internal felsic stocks. The former environment is associated principally with splays of the SLDZ (Figure 004.2). The spatial association of alteration and veining with respect to intensity and geometry of fabric development is similar to that described for the area to the south (Beakhouse 1985).

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005. Birch Lake Area (Eastern Half), District of Kenora (Patricia Portion)

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INTRODUCTION

The Birch Lake Area (eastern half), is centred approximately 120 km northeast of Red Lake. The area is part of the northeastern part of the Birch-Uchi Greenstone Belt, of the Uchi Subprovince. Mapping in 1986, the second year of a two-year project, covered the northern half of the area, bounded by Latitudes 51°21′45″N and 51°27′15″N and Longitudes 92°06′00″E and 92°23′00″E, an area of 190 km^2. Some parts of the area covered in 1985 were also re-examined. The geology of the southern half was reported by Good (1985) and Good *et al.* (1986). An area of similar size is currently being mapped by Beakhouse (1985, this volume).

Access to Birch Lake is by float-equipped aircraft from Red Lake. Canoe access is possible from the South Bay Road which extends north from Highway 105 at Ear Falls, but requires several portages. Most of the map area, except the eastern part, is accessible from Birch Lake.

MINERAL EXPLORATION

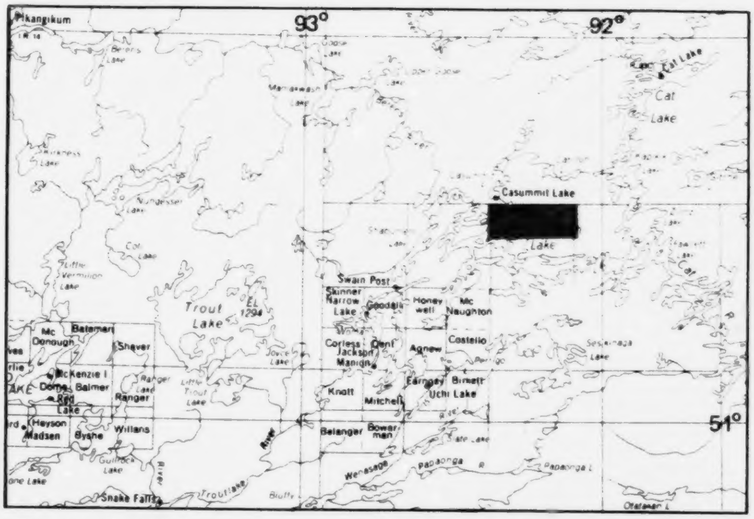
Several exploration companies are actively exploring for gold in the area. Information on exploration activity, prior to 1985, has been summarized by Good *et al.* (1986). The three main areas of economic interest (indicated by the symbol Au on Figure 005.1) have been recently, or are presently being, reexamined. The east-trending shear zone on the northern shore of Birch Lake has been examined for gold at the eastern end near Penson Lake, and at the western end in the Saw Mill Bay (local name) of Birch Lake. In 1960, a joint operation by New Dickenson Mines Limited, Alcon Exploration Limited, and Mining Syndicate Limited diamond drilled 14 holes totaling 1280 feet at the western end of the shear zone. In 1968, Mentor Exploration and Development Company Limited put down 8 trenches and completed 6 diamond-drill holes at the eastern end of the zone. The area was reassessed and geologically mapped in 1979 by Cominco Limited. H.A. Crawford conducted a magnetic and electromagnetic survey over the eastern end of the shear zone in 1985.

On the property at the eastern end of Birch Lake, Canamer Mining Corporation diamond drilled seven holes and conducted geological mapping in 1966. This property was reassessed and geologically mapped in 1979 by Cominco Limited. Dome Exploration Limited conducted a ground electromagnetic and magnetic survey over the property in 1984, and continued geological mapping and diamond drilling in 1986.

The property near the portage between Springpole and Birch Lakes was geologically mapped in 1936 by Windikogan Sturgeon Mining Syndicate. Windikogan Sturgeon Mining Syndicate diamond drilled ten holes totalling 1477 feet and put down several trenches. This property is currently being examined by Gold Fields Canadian Mining Limited.

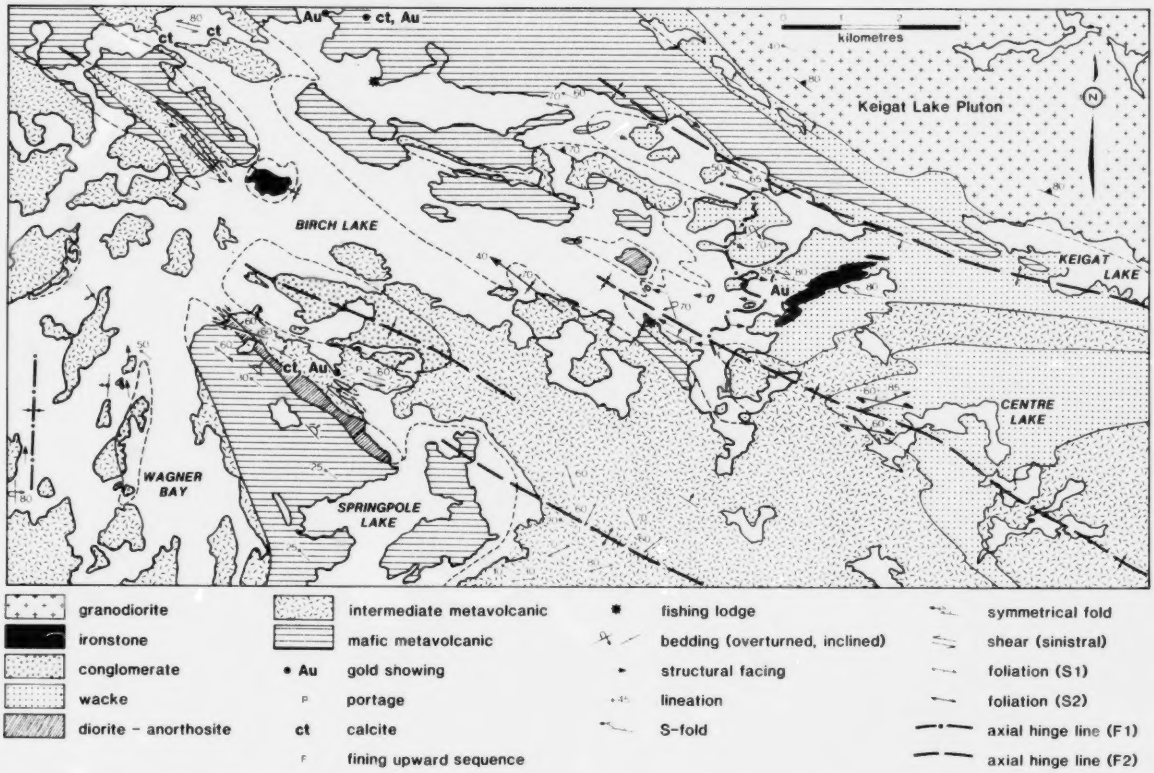
GENERAL GEOLOGY

The map area is underlain by interlayered mafic and intermediate metavolcanics and metasediments of Archean age, which are locally covered by glacial deposits. The Birch Lake area was previously mapped by Harding (1936), Thurston *et al.* (1981), and Thur-


Pikangikum
93°
92°
Cat Lake
Cat Lake
Casummit Lake
Lake
Swain Post
Skinner Narrow Lake
Goodall
Honeywell
Mc Naughton
Trout Lake
Mc Donough
Bateman
Shever
Costello
Corless
Jackson Manion
Agnew
McKenzie I.
Dome
Balmer
Red Lake
Ranger
Knott
Mitchell
Earngey
Birnett
Uchi Lake
Heyson
Madsen
Byshe
Willans
Belanger
Bowerman
51°
River
Snake Falls
Wenasaga
Papaonga

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles



ct, Au
Au
ct
ct
kilometres
Keigat Lake Pluton
N
BIRCH LAKE
KEIGAT LAKE
Au
ct, Au
CENTRE LAKE
WAGNER BAY
SPRINGPOLE LAKE
granodiorite
ironstone
conglomerate
wacke
diorite - anorthosite
intermediate metavolcanic
mafic metavolcanic
Au gold showing
P portage
ct calcite
F fining upward sequence
fishing lodge
bedding (overturned, inclined)
structural facing
lineation
S-fold
symmetrical fold
shear (sinistral)
foliation (S1)
foliation (S2)
axial hinge line (F1)
axial hinge line (F2)

Figure 005.1. *General geology and structure of the Birch Lake area (eastern half).*

ston (1986) at reconnaissance scale. Goodwin (1967) examined part of the area during a volcanic study of the Birch-Uchi Lakes Area.

Stratigraphy in the south central portion of the map area, around Springpole Lake, strikes southeasterly. The metasediments and intermediate pyroclastic rocks of Wagner Bay strike south and are a continuation of sequence 2 of the 1985 map area (Good *et al.* 1985). The further division of rock types into sequences around Birch Lake is difficult due to the complexities of folding.

Mafic metavolcanics occur throughout the map area, usually interlayered with either metasediments or pyroclastic rocks (Figure 005.1). The mafic metavolcanics around Springpole Lake and Johnson Island of Birch Lake are similar. They are mainly fine-grained, dark green massive flows and minor pyroclastic rocks. Pillowed flows are less common than massive flows. The flows commonly contain fine to very coarse (up to 15 cm) phenocrysts of plagioclase feldspar. The abundance, size, and nature of the plagioclase in these mafic rocks is very similar to those in Sequence 3 of the area to the south, mapped in 1985 (Good 1985).

Thin, medium- to coarse-grained mafic sills intrude all lithologies in the map area except the Keigat Lake pluton in the northeastern corner of the area. The sills contain up to 25 percent mafic phenocrysts, usually less than 1 cm in size.

Two layered sills, possibly related to the mafic metavolcanic sequence, outcrop on Birch Lake (Figure 005.1). They are both dioritic to anorthositic in composition. The sill at the eastern end of Birch Lake is anorthosite, consisting of coarse-grained subhedral to euhedral plagioclase. Layering is defined by rapid changes in grain size which ranges from less than 1 cm to 5 cm.

The sill south and west of the portage to Springpole Lake consists of medium- to coarse-grained plagioclase-rich layers of dioritic to anorthositic composition. No fractionated mafic or ultramafic portions of these sills were found.

Intermediate pyroclastic rocks make up a large portion of the map area. They include, in decreasing order of abundance, feldspar crystal tuff, tuff, lapilli-tuff, lapilli-stone, and tuff-breccia. They show a wide range in colour, texture, degree of reworking, and clast and matrix composition. Some units in the northwestern corner of the map area contain 1 to 5 percent accidental fragments of sediment, ironstone, or quartz. Both reverse and normal grading were noted west of the portage between Springpole and Birch Lakes, and on an island north of the fishing lodge on the southeastern shore of Birch Lake.

Metasediments comprise distinct stratigraphic sequences in the Birch Lake Area, but thin layers of metasediment also occur interlayered with the metavolcanics. The stratigraphic sequences consist mainly of thinly bedded wacke-mudstone, wacke-siltstone, or wacke-ironstone assemblages and subordinate conglomerates.

The graded wacke assemblages show AE or ACE Bouma subdivisions which are characteristic of turbidite. A fining upward sequence of metasediments occurs just east of the fishing lodge on the southeastern shore of Birch Lake. Here, thickly bedded arenaceous wacke grades to thinly bedded and graded wacke/siltstone and finally to thinly bedded wacke/laminated ironstone.

Metasediments found interlayered with the metavolcanics mainly consist of very thinly bedded to laminated siltstone or ironstone and subordinate wacke.

A thick sequence of heterolithic, paraconglomerate strikes east-west along the peninsula north of the portage between Springpole and Birch Lakes. The conglomerate consists of well-rounded cobbles to boulders which are in places imbricated. Clasts of laminated wacke are found. Irregular lenses of arenite, arenaceous wacke, and pebbly wacke are found throughout the unit. These finer lenses of metasediment are frequently graded and occasionally show soft-sediment deformation structures.

The volcano-sedimentary sequence was intruded by the Keigat Lake Pluton in the northeastern corner of the map area. It consists of coarse-grained, equigranular, homogeneous granodiorite with scattered porphyritic zones with large (2 to 3 cm) phenocrysts of potassium feldspar. The pluton has a very fresh appearance and exhibits a weak schistosity defined by biotite flakes and faint lineation. The schistosity strikes parallel to the contact and dips steeply north. The lineation trends approximately 300° and plunges at 45°. This pluton has a similar composition to the Springpole Lake Stock, located to the south (Good 1985) but the Springpole Lake Stock has been deformed.

Regional metamorphic grade is lower amphibolite facies (Winkler 1979) similar to that determined for the area to the south (Good 1985).

A contact metamorphic aureole up to 2 km wide surrounds the Keigat Lake Pluton. Within this zone the mafic metavolcanics have been metamorphosed to mid to upper amphibolite facies and the metasediments contain up to 30 percent garnet.

STRUCTURAL GEOLOGY

The major lithological units of most of the map area trend northwesterly parallel to stratigraphy described for the 1985 map area. However, the metasedimentary-pyroclastic package in Wagner Bay strikes approximately north.

Bedding, except in the hinge zones of folds, strikes northwesterly and dips at 30° to 85° north. Younging directions are both north and south. Those which face south are, therefore, overturned. In Wagner Bay the metasediments and metavolcanics trend near north and dip 40° to 80° west. Younging directions are west, but units along the western map boundary face east, and these are, therefore, overturned.

In general, a regionally pervasive foliation strikes 270° to 330° with dips 50° north to vertical. A weak schistosity in the Keigat Lake Pluton strikes parallel to the contact with the country rocks and the regional foliation. A previous foliation is folded in several locations on Springpole, Birch, and Seagrave Lakes. In areas where the early foliation is folded, the crenulation cleavage is parallel to that of the regionally pervasive foliation.

The trend of lineations is very consistent across the map area even into Wagner Bay. The trend varies from 280° to 330° and plunge 10° to 50°. The plunge of the lineation in the metavolcanic-metasedimentary units around Springpole Lake is between 10° and 30°, but steepens to 40° to 50° to the north. The lineations are approximately parallel to the mineral lineation within the Keigat Lake Pluton.

Parasitic folds in the central and eastern portion of the map area have fold axes that trend and plunge at approximately 300° and 50°, respectively. Axial hinge planes strike at approximately 280° and dip 75° north. In these small folds an axial planar cleavage parallel to the regional foliation is preserved.

The regional northwest foliation is, therefore, assumed to be axial planar. Regional folding is characterized by synformal anticlines and antiformal synclines with fold axes and hinge lines parallel to the parasitic folds described above. Structural facing directions, determined using the axial planar cleavage and younging directions (Borradaile 1976), are to the east, but there are several reversals in the metasedimentary package at the eastern end of Birch Lake (Figure 005.1).

In conclusion, micro-, macro-, and mega-scopic folding of a previous foliation, and the frequent reversals in structural facing directions, indicate that the Birch Lake area has undergone at least two major periods of deformation (D_1 and D_2). The present northwest trend of most of the stratigraphy is a result of folding along northwest-trending folds during D_2. The northerly trend of the metasediments and pyroclastic rocks and their schistosity in Wagner Bay is interpreted to be the result of the D_1 folding event which was subsequently only weakly affected by D_2.

In Figure 005.1 the sequence of metasediments at the eastern end of Birch Lake is complexly folded. The relationships between bedding and cleavage planes and parasitic folds were used to construct the series of overturned synclines and anticlines. The F_1 fold axis was determined using reversals of structural facing directions.

There are two major shearing trends in the map area, and, in any one locality, either shear trend may dominate. Lineations on both sets of shear planes plunge 30° to 60° northwest. Both shear trends are seen on a single outcrop located at the northwestern end of the layered dioritic sill southwest of the portage to Springpole Lake. Here the shearing is interpreted to be a conjugate set. Shear planes which strike approximately 270° to 290° and dip at 70° to 80° north are sinistral and conjugate to the dextral shear planes which strike 310° to 320° and also dip 70° to 80°north. These conjugate shear sets are consistent with a northeast-southwest flattening (F_2) and an extension which also formed the lineation (L_2) during the second deformational event (D_2) and are, therefore, interpreted to have formed during the later stages of D_2.

ALTERATION

The map area is marked by localized chlorite alteration and widespread carbonate alteration of variable intensity. The chloritic alteration occurs to the east and west of the portage to Springpole Lake. It consists of massive chlorite along brittle fracture surfaces with chlorite enrichment haloes surrounding the fractures.

The intensity of carbonate alteration varies across the map area although it increases with increasing deformation. In general, the carbonate veins intrude along planes of weakness related to D_2 and are usually undeformed, indicating that carbonate alteration occurred either during the final stages or after D_2. There are three levels of intensity of carbonate alteration, the first of which is relatively unimportant. The lowest level of carbonate alteration consists of infilling of vesicles in mafic flows and intermediate pyroclastic rocks and the selective growth of calcite crystals (up to 1 cm) in the muddy layers of some wacke/mudstone turbidite units.

The second form of carbonate alteration consists of massive orange-red carbonate emplacement along bedding planes, pillow selvages, cleavage planes, and shear planes, and into the noses of folds. In several locations on Birch Lake, layers of massive carbonate are up to 50 cm thick. Similar occurrences are found on Seagrave Lake located approximately 12 km to the south.

The most intense alteration is pervasive carbonate alteration seen near the shear zones. Gold mineralization is found spatially associated with pervasive carbonate alteration at three locations on the shore of Birch Lake (indicated by Au on Figure 005.1).

ECONOMIC GEOLOGY

There are three gold showings around the shoreline of eastern Birch Lake (Figure 005.1). All three showings are similar in that gold is associated with carbonate alteration, quartz veining, and minor disseminated sulphide mineralization. They are also localized within D_2 structures; the two showings on the northern and southern shores are located in east-west sinistral shear zones, and the showing on the eastern shore is localized within the nose of parasitic fold structures. Available gold values for the deposits include 0.1 ounce gold per ton over 5 feet at the deposit on the northern shore (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)), 0.56 ounce gold per ton over 1.5 feet at the deposit on the eastern shore (Edmond 1966), and 1.82 ounces gold per ton over 3.5 feet at the property near the portage (AFRO). The sulphide mineralization reported in the three deposits include, in decreasing order of occurrence, pyrite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and galena. Visible gold was noted in all of the deposits.

Exploration for gold using electromagnetic and magnetic geophysical techniques has proved to be of limited value in the area because:

1. The gold bearing zones only contain disseminated sulphide mineralization, consisting mainly of pyrite, which is nonmagnetic.
2. The gold bearing zones are parallel to stratigraphy and the stratigraphy consists of interlayered rock types with highly variable magnetite contents.

A recommended technique of exploration would be to concentrate on intensely deformed areas where carbonate alteration, disseminated sulphide mineralization, and quartz veining are evident. Because of the disseminated pyrite, the mineralized zone could then be possibly outlined by an induced polarization geophysical survey.

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006. Lake of the Woods Structural Study

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

This report summarizes the results of the first year of a two-year program designed to provide an integrated stratigraphic and structural framework for the Lake of the Woods region of northwestern Ontario. Field work during the summer of 1986 was concentrated in the northern part of Lake of the Woods, in an area bounded by Latitudes 49°35′N and 49°55′N and Longitudes 94°05′W to 94°45′W. Access to the area is gained from Lake of the Woods. The Dryberry Granitoid Complex in the eastern part of the area is transected by Highways 17 and 71.

Detailed geological mapping of the study area (on a scale of 1:15 840) was conducted during 1984 and 1985 by Ayer (1984, 1985a), to which the reader is referred for a description of the general geology and mineral occurrences of the area. The major stratigraphic units and intrusive bodies in the area are shown in Figure 006.1.

Specific objectives of this project were as follows:

1. To establish the intensity and character of strain in the northern part of the greenstone belt.
2. To establish the lateral extent and mechanics of the shear zones which transect the map area; to determine whether the shear zones are early structures, or related to late regional-scale subhorizontally directed oblique compression (transpression).
3. To investigate age relationships between stratigraphic units and structural events; specifically, to compare and contrast the state of deformation of "Timiskaming-type" sedimentary rocks with "Keewatin" strata.
4. To establish the width of the contact strain aureole imposed by the Dryberry Granitoid Complex upon the Lake of the Woods Belt; to determine the effect of contact strain upon stratigraphy; to determine, if possible, which granitoid bodies are responsible for the various strain events.
5. To develop a tectono-stratigraphic model for this part of the western Wabigoon Subprovince which will be tested by U-Pb zircon geochronology in the near future.

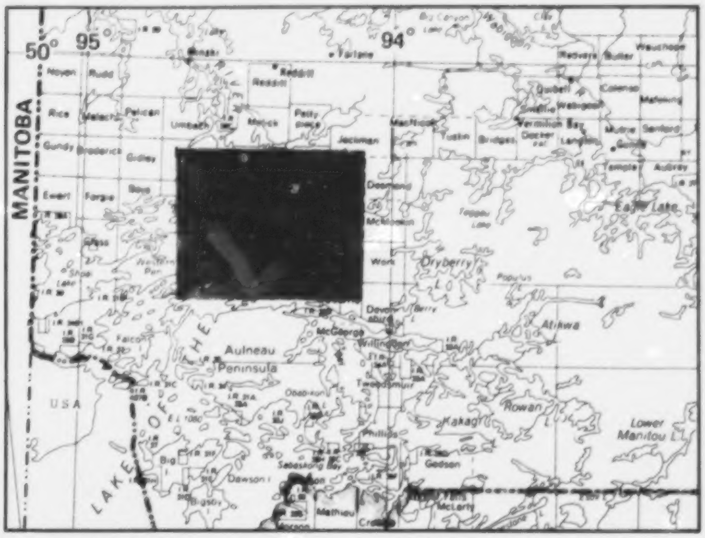
This work will continue during 1987, and will be extended as far south as the Aulneau Peninsula. Emphasis will be placed on integrating mineral deposits into the established tectono-stratigraphic framework.

This project is being carried out at a scale of 1:50 000. Field observations are recorded and stored on a NEC PC-8200 computer to facilitate tabulation and processing of structural data.

REGIONAL STRUCTURE AND STRATIGRAPHY

Various structural elements such as foliations, lineations, and folds were systematically measured and recorded across the study area. General structural trends recognized at present include the following:

1. A steeply dipping, flattening fabric is developed across the region. This fabric appears to be axial planar to major first order folds (shown on Figure 006.1), and is interpreted to have formed during this major folding (D_1) event.



LOCATION MAP Scale : 1:1 584 000 or 1 inch to 25 miles

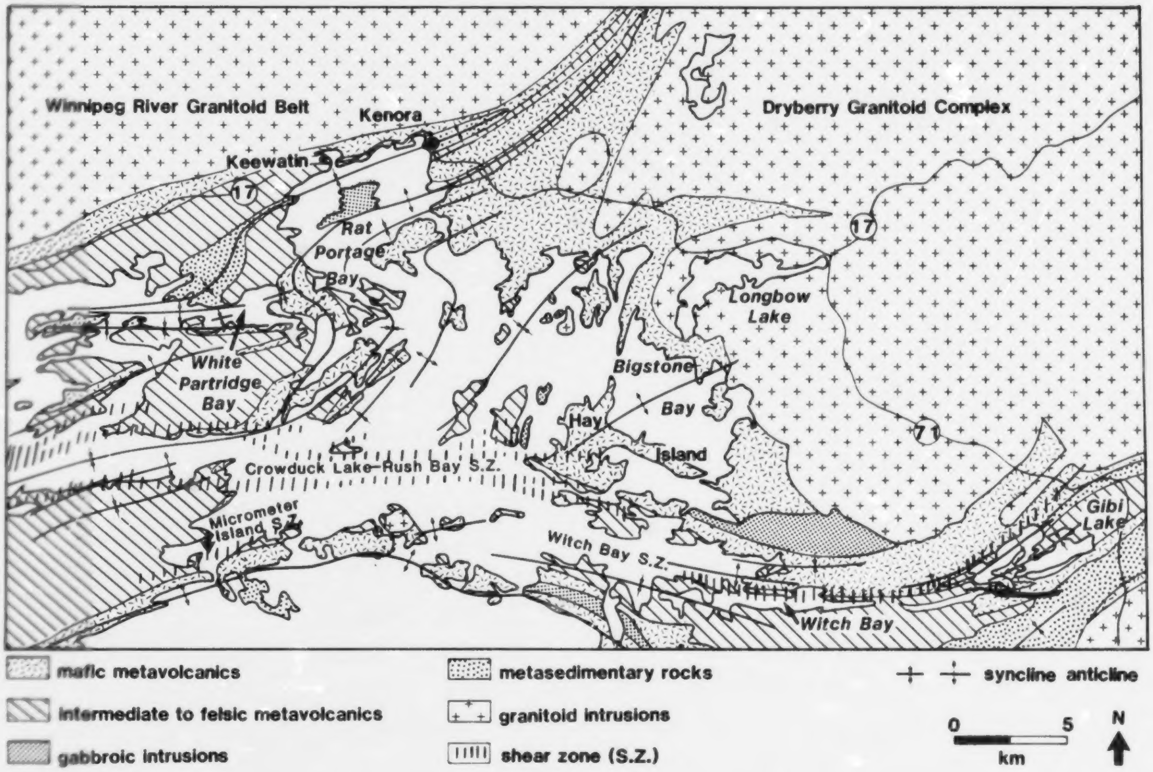

Winnipeg River Granitoid Belt
Kenora
Dryberry Granitoid Complex
Keewatin
17
Rat Portage Bay
Longbow Lake
White Partridge Bay
Bigstone Bay
Hay Island
71
Crowduck Lake-Rush Bay S.Z.
Micrometer Island S.Z.
Witch Bay S.Z.
Gibi Lake
Witch Bay
mafic metavolcanics
intermediate to felsic metavolcanics
gabbroic intrusions
metasedimentary rocks
granitoid intrusions
shear zone (S.Z.)
syncline anticline
0
5
km
N

Figure 006.1. *Stratigraphy and structure of northern Lake of the Woods.*

2. A tectonic fabric associated with a D_2 event is not recognized. The development of east-striking deformation zones and buckle folding of a major D_1 fold structure (*see* 6. below) suggest that north-northwest shortening (D_2) postdated the D_1 event. North-northwest shortening appears to have transposed the early D_1 fabric, and hence, overprinting fabrics are not observed.
3. Mineral lineations have a moderate to steep (60°-70°) plunge, except within high strain zones where lineations consistently plunge down the dip of the foliation.
4. Mineral lineations show a tendency to plunge eastward in the eastern half of the belt, and westward in the western half.
5. Regional folding of volcanic stratigraphy is represented by fold axial traces that trend northeast to eastward. Map patterns suggest that major northeast-trending folds plunge steeply southwest.
6. Buckling of north-south structures is observed in the northern portion of the belt. This is illustrated in the Rat Portage Bay area (Figure 006.1) where buckle folds are developed along a major northeast-trending D_1 fold, and also along the north-trending margins of a gabbroic intrusion.
7. There is a general absence of outcrop scale fold hinges.

DEFORMATION ZONES

Three dominant high strain zones transect the northern part of Lake of the Woods: the Crowduck Lake Shear Zone, the Witch Bay Shear Zone, and the Micrometer Island Shear Zone (Figure 006.1).

The Crowduck Lake and Witch Bay Shear Zones have recently been interpreted by Ayer (1984) as a continuous structure, joined via southeasterly shearing in the vicinity of Hay Island. However, preliminary examination of the Hay Island region revealed that the rocks are only weakly deformed. East-trending shear fabrics are locally developed and southeasterly shearing is developed only to a minor extent. Field evidence that the Crowduck Lake and Witch Bay Shear Zones are continuous through this area is not clear, and more detailed mapping is necessary before the relationship between these two shear systems can be established.

The Crowduck Lake Shear Zone is the most extensive system, extending from the Ontario-Manitoba border to the Dryberry Granitoid Complex in the east (Blackburn 1981; Ayer 1984). Within the study area the east-trending shear zone is approximately 2 km wide and transects predominantly intermediate to felsic volcanic rocks. The shear zone is characterized by steep easterly plunging mineral lineations and shows evidence of major reverse, north-side-up displacement. Locally, horizontal surfaces display S fabric (schistosity) rotated into east-trending C fabric (shear planes) consistent with transcurrent dextral displacement. These fabrics may reflect reactivation of the shear zone. Steeply plunging kink folds with S and Z asymmetry are developed within the shear zone. It is evident from the geometry of the kink folds that subhorizontal shortening across the shear zone has taken place.

The Witch Bay Shear Zone is exposed along the northern shore of Witch Bay in the southeastern part of the study area (Figure 006.1). The 200 m wide shear zone trends roughly east-west, but varies in strike from 290° at the mouth of Witch Bay, to 260° at the head of the bay, 6 km to the east. The shear zone can be continuously traced to the northeast for at least 12 km, along the northern shore of Gibi Lake (Trowell, in press). Subvertical, north-side-up displacement is evident along the shear zone by virtue of steeply plunging mineral lineations and shear bands corresponding to C′ fabric development. Shallowly plunging asymmetric "S" kink folds are interpreted as a brittle product of this deformation. Both, the conformable geometry of the Witch Bay Shear Zone to the granite/greenstone contact to the north, and the shear zone displacement in a north-(batholith)-side-up sense, suggest that shearing along the Witch Bay structure is mechanically related to the emplacement of the granitoids to the north. This is further supported by field evidence in the Gibi Lake area where shearing of the marginal portion of the granitic intrusion suggests syn-emplacement timing for shear zone development (Trowell, in press).

Alteration is pervasive in all lithologies transected by the Crowduck Lake and Witch Bay Shear Zones. Alteration has generally involved widespread iron-carbonatization. Sericitization has commonly affected sheared felsic volcanic assemblages.

The Micrometer Island Shear Zone transects intermediate pyroclastics in the southwestern part of the study area (Figure 006.1). Subvertical, south-side-up displacement within this zone suggests that the Micrometer Island Shear Zone may be a conjugate of the Crowduck Lake Shear Zone to the north. Contemporaneous displacement on these structures may have caused downfaulting of intervening intermediate to felsic volcanic rocks, and their subsequent preservation through the centre of the belt (Figure 006.1). Alternatively, the Micrometer Island Shear Zone may represent a structural break associated with thrusting from the south.

VOLCANIC/SEDIMENTARY CONTACT AND STRUCTURAL RELATIONSHIPS

The White Partridge Bay Group metasediments are located in the northeastern part of the map area (Figure 006.1). The sequence is interpreted by Ayer (in preparation) as a coarsening upwards fluviatile succession which, by analogy with similar terrains elsewhere, is considered to unconformably overlie Keewatin strata. As such, the White Partridge Bay Group is potentially correlative with the Crowduck Group, to the west, which does unconformably overlie the Keewatin (Beakhouse 1985).

One objective of this study was to examine the state of deformation within the White Partridge Bay metasediments and the underlying metavolcanics. During this examination, localities along the sedimentary/volcanic interface were mapped in detail in an attempt to clearly establish the nature of contact relationships.

In general, a moderate to weak strain intensity is observed throughout the metasedimentary sequence. This level of strain is uniformly observed across the volcanic/sedimentary interface and characterizes the immediately underlying volcanic rocks. The sedimentary sequence is folded about east-northeast-trending fold axes. Younging directions and the trace of major fold axes within both the sedimentary and volcanic sequences are consistent with a single folding event. Folds of shorter wavelength are developed within the sedimentary sequence relative to the volcanic pile. This is particularly notable at the sedimentary-volcanic interface, and suggests that fold size is, in part, a function of ductility contrast between sedimentary and volcanic strata. A tectonic fabric is associated with the folding event. Cleavage within the sedimentary rocks strikes at 110° and within the adjacent volcanic rocks strikes at 090°. This cleavage is not axial planar to the folds, and is identified as a transected cleavage (Borradaile 1978) which may have developed at a relatively late stage in the folding event. The 10° to 20° variation in the strike of cleavage between the two major units may be attributed to regional-scale cleavage refraction. Cleavage refraction of 15° from volcanic to sedimentary rock can be observed on the scale of the outcrop (Locality C, Figure 006.2).

Detailed mapping was conducted at four localities across the sedimentary-volcanic interface. These localities are labelled A to D in Figure 006.2 and are represented by simplified stratigraphic sections. At locality A, tuff, overlying pillowed flows, grades imperceptibly into clastic sedimentary rocks of very similar composition. Sedimentary units can be distinguished from bedded pyroclastics by virtue of detrital quartz, graded bedding, and thin interbeds of argillaceous sediments. Sedimentary bedding is conformable to bedding of the underlying volcanic rocks. Top reversals indicate tight folding within sedimentary units at the interface; however, younging of the uppermost volcanic rocks and the lowermost sedimentary rocks is to the north.

At locality B, poorly bedded, poorly graded, coarse-grained feldspathic wackes directly overlie altered, mafic, pillowed flows. The sedimentary succession is interrupted by a 40 cm wide horizon of vesicular volcanic material which lies 3 m north of the volcanic-sedimentary interface. The volcanic horizon can be continuously traced for over 30 m along strike.

At locality C, highly transposed slaty argillites are infolded with intermediate to felsic volcanic rocks. Bedding within the volcanic sequence is parallel to the volcanic-sedimentary contact. Structural facing (cf. Borradaile 1976) of sedimentary units at the contact is to the southwest, away from the volcanic pile.

At the northern margin of the sedimentary sequence (locality D), thin wacke beds are intermittently interbedded with amphibole-rich mafic tuff. This transitional horizon is underlain by intermediate tuff breccia, and overlain by an extensive sequence of very fine feldspathic siltstones.

In summary, field relationships at a regional and outcrop scale are compatible with a conformable contact between volcanic rocks of Keewatin age and the overlying White Partridge Bay Group of metasediments. The metasedimentary sequence had been interpreted by Thomson (1937) as a Timiskaming-type sedimentary succession which was unconformably overlying Keewatin volcanic rocks. His evidence for an unconformity was based upon a single occurrence of pronounced angular discordance in orientation of bedding across the contact. Although this locality was not examined by the author, recent mapping by Ayer and Gil (1986) indicates that discordant bedding relations cannot be demonstrated in this area.

DRYBERRY GRANITOID COMPLEX

The Dryberry Granitoid Complex occupies 2000 km^2 to the east of the Lake of the Woods metavolcanic belt (Figure 006.1). The western part of the granitoid complex is dominated by foliated, biotite-bearing tonalite to quartz-diorite (Figure 006.3a). Biotite-phyric tonalite exists as an extensive mappable phase from north of Longbow Lake to the Gibi Lake metavolcanics in the southeast (Figure 006.3a). Amphibole (hornblende) is present in tonalite at the margin of the greenstone belt, and in tonalite adjacent to amphibolite inclusions within the complex. Tonalitic units typically contain evenly disseminated euhedral magnetite. As a result, the western part of the complex is characterized by a relatively high magnetic response (ODM-GSC 1963, 1970).

Minor granodioritic to leucogranodioritic phases are exposed northeast of Longbow Lake and west of Gibi Lake (Figure 006.3a).

Gneissic tonalite was observed at two localities in the western part of the complex (Figure 006.3a). These localities are distinct from the main mass of the complex by virtue of their heterogeneous gneissic texture. These rocks are heavily cut by foliated to massive tonalitic and granodioritic dikes and contain abundant amphibolite interlayers and inclusions.

The western part of the complex can be subdivided into discrete domical structures on the basis of foliation and mineral lineation patterns (Figure 006.3b). A primary (post-tectonic) emplacement fabric, conformable to the margins of individual domical structures, is exhibited throughout the main mass of the complex. On this basis, these structures are interpreted to represent late- to post-tectonic plutons. In general, mineral lineations are steep near the centres of individual domical structures and become progressively more shallow toward the margins of the domes. This pattern indicates that *in situ* expansion, or ballooning (Ramsay 1981) has taken place, and that the complex is presently exposed at a mid-erosional level. Gneissic tonalite and amphibolite occur at the interface between individual structures. On the basis of this distribution, and the gneissic texture exhibited at these localities, these rocks are inter-

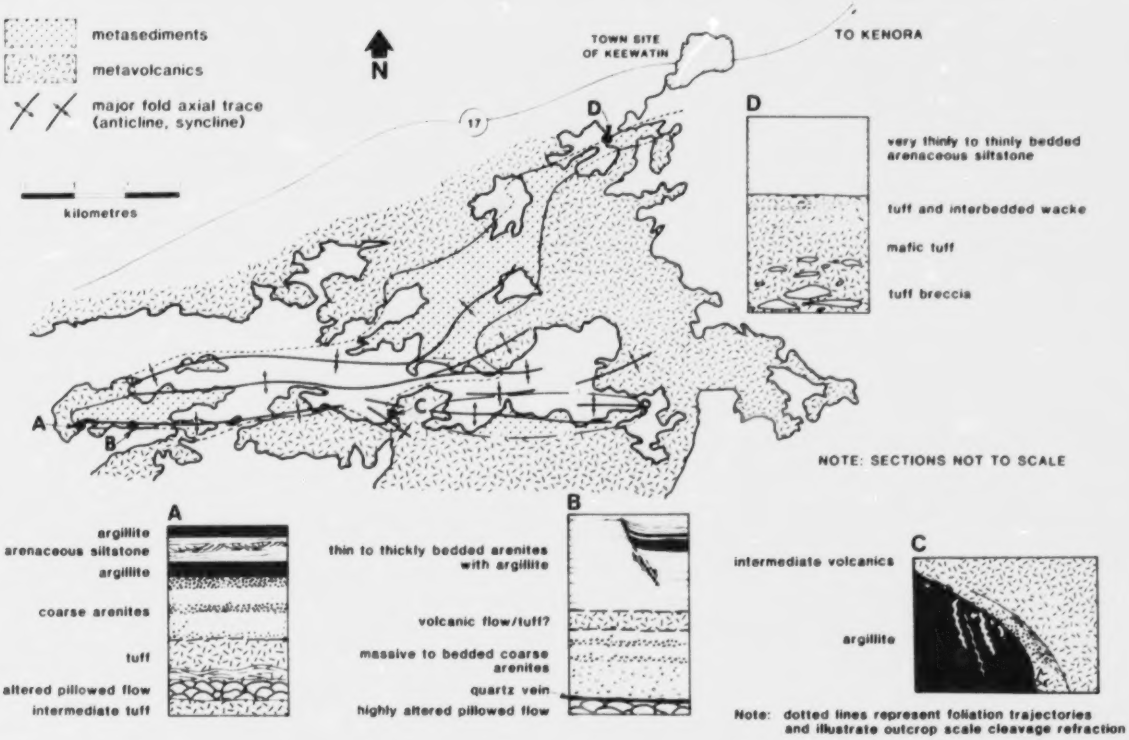

metasediments
metavolcanics
major fold axial trace (anticline, syncline)
kilometres
N
TOWN SITE OF KEEWATIN
TO KENORA
17
D
A
B
C
D
very thinly to thinly bedded arenaceous siltstone
tuff and interbedded wacke
mafic tuff
tuff breccia
NOTE: SECTIONS NOT TO SCALE
A
argillite
arenaceous siltstone
argillite
coarse arenites
tuff
altered pillowed flow
intermediate tuff
B
thin to thickly bedded arenites with argillite
volcanic flow/tuff?
massive to bedded coarse arenites
quartz vein
highly altered pillowed flow
C
intermediate volcanics
argillite
Note: dotted lines represent foliation trajectories and illustrate outcrop scale cleavage refraction

Figure 006.2. Distribution of the White Partridge Bay Group metasediments and underlying Keewatin volcanic rocks. Modified from Ayer and Gil (1986).

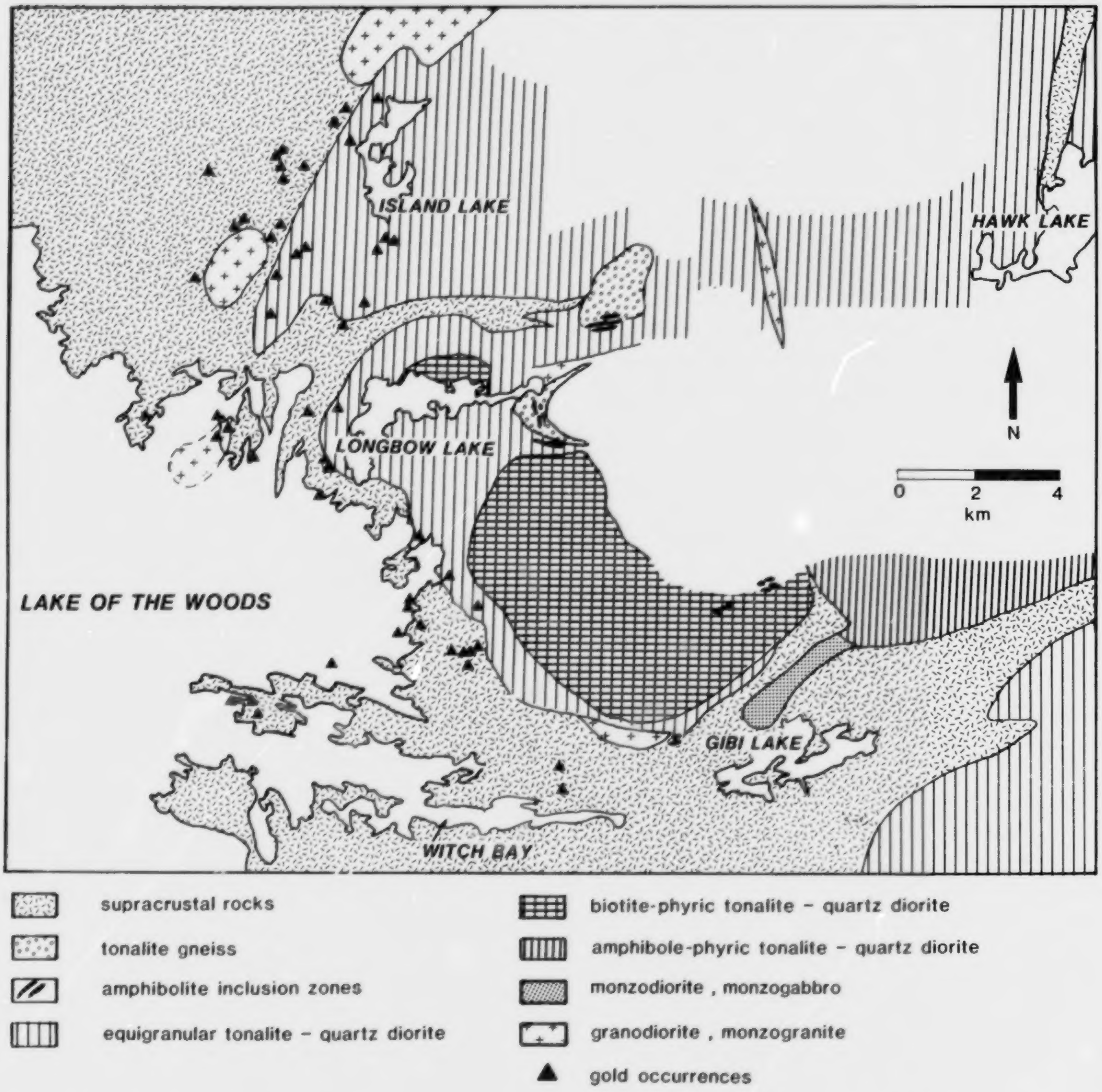
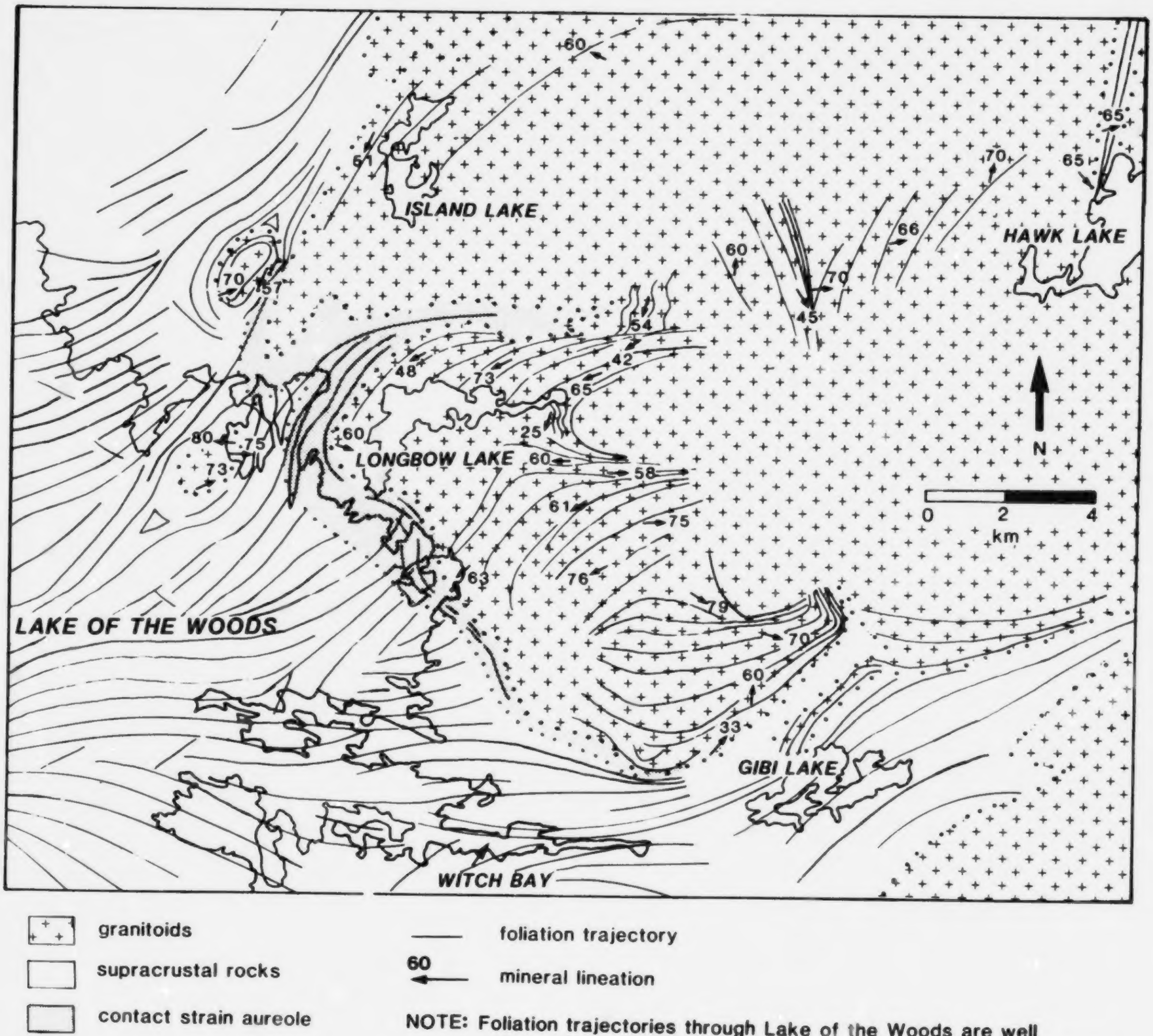

ISLAND LAKE
HAWK LAKE
LONGBOW LAKE
N
0
2
4
km
LAKE OF THE WOODS
GIBI LAKE
WITCH BAY
supracrustal rocks
tonalite gneiss
amphibolite inclusion zones
equigranular tonalite – quartz diorite
biotite-phyric tonalite – quartz diorite
amphibole-phyric tonalite – quartz diorite
monzodiorite , monzogabbro
granodiorite , monzogranite
gold occurrences

Figure 006.3a. *Geology of the western Dryberry Granitoid Complex. General lithology and location of known gold occurrences.*

preted to be pre-tectonic. The north-south gneissosity exhibited by these units is deformed by open buckle folds that appear to have developed during expansion of the late intrusions to the north and south.

Foliation trends within the metavolcanics deviate near the late plutons (Figure 006.3b) and this is interpreted to reflect an envelope of contact strain imposed by these plutons. The nature and width of the contact strain aureole is variable along the western margin of the granitoid complex. Mafic metavolcanics west of Longbow Lake are characterized by a strong vertical extension fabric. Zones of pure and simple shear are extensively developed within the contact strain aureole, parallel to the granite-greenstone interface. Simple shear zones clearly indicate major dip-slip (batholith-side-up) displacement. Toward the south, contact strain effects become increasingly more subtle and the width of the aureole appears to decrease to approximately 800 m. Field evidence suggests that the intrusion has stoped gently into place along this interface. Supporting evidence includes:

1. scalloped geometry of the granite-greenstone interface
2. recrystallized hornfels texture of the metavolcanics
3. a narrow contact strain aureole which contains only a weak to very weak fabric parallel to the granite/greenstone interface


ISLAND LAKE
HAWK LAKE
LONGBOW LAKE
LAKE OF THE WOODS
GIBI LAKE
WITCH BAY
N
0
2
4
km
granitoids
supracrustal rocks
contact strain aureole
foliation trajectory
60
mineral lineation

NOTE: Foliation trajectories through Lake of the Woods are well constrained by data collected from islands not shown on this map.

Figure 006.3b. *Geology of the western Dryberry Granitoid Complex. Structural patterns.*

4. an absence of pure or simple shear zones parallel to the interface
5. an absence of complex diking relationships at the contact which would have been indicative of forceful intrusive injection

It is significant to note that a large number of gold occurrences are localized in mafic metavolcanics within, and adjacent to, the contact strain aureole imposed by the Dryberry Granitoid Complex (Davies and Smith 1984; Ayer 1984; Ayer *et al.* in preparation; Figure 006.3). This relationship will be investigated during the 1987 field season.

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007. Geology of the Clearwater Bay Area, Lake of the Woods, District of Kenora

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Field investigations in 1986 are a westward extension of detailed geological mapping of the northern part of Lake of the Woods begun in 1984 in the Bigstone Bay area, and continued in 1985 in the Rat Portage Bay area. This summer an area of about 220 km^2 was mapped, bounded by Latitudes 49°37'N to 49°45'N and Longitudes 94°40'W to 94°53'W.

Access to most of the area is from Lake of the Woods. The northern part is most easily reached from both Highway 17 and numerous secondary roads.

MINERAL EXPLORATION

Information on exploration work done in the area is derived from the Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Kenora (RGFK).

The area has been actively explored for gold since the Lake of the Woods "Gold Rush" of the early 1880s. In recent years, the area underlain by the Canoe Lake Stock, in the southwest, has also been explored for porphyry copper and molybdenum.

Homestake Mineral Development Company currently has 90 claims within the map area as part of a large group staked along the Crowduck Lake-Witch Bay Shear Zone. The claims were covered by an airborne geophysical survey in 1985.

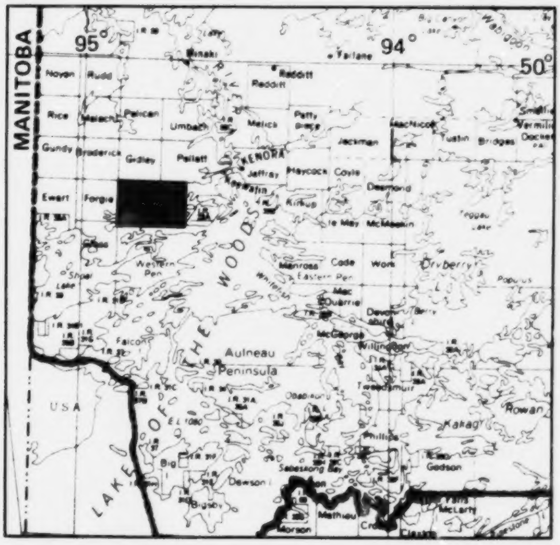
Gordon Pogson currently holds a group of 21 claims on the Three Friends Occurrence (I, Figure 007.1). In 1981, Denison Mines Limited conducted ground geophysical, geochemical, and geological surveys on this property.

Noranda Exploration Company Limited staked 4 claims on the Gauthier Occurrence (C) this summer. This occurrence, plus the Echo Bay (A) and the Nonesuch (F) Occurrences, were held from 1979 to 1985 by Tasu Resources Limited. Work done during this period included: ground geophysical, geochemical, and geological surveys, resampling old workings, and three diamond-drill holes totaling 315 m in length.

In 1983, the area around the Inglis Lake Occurrence (E) was geologically mapped by Atikwa Resources Incorporated.

In 1975, Hudson Bay Exploration and Development Company Limited diamond drilled six holes within a broad area south of the western end of Zig Zag Island.

In 1971, Kerr Addison Mines Limited diamond drilled 10 holes within a broad area on and around Corkscrew Island.



LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

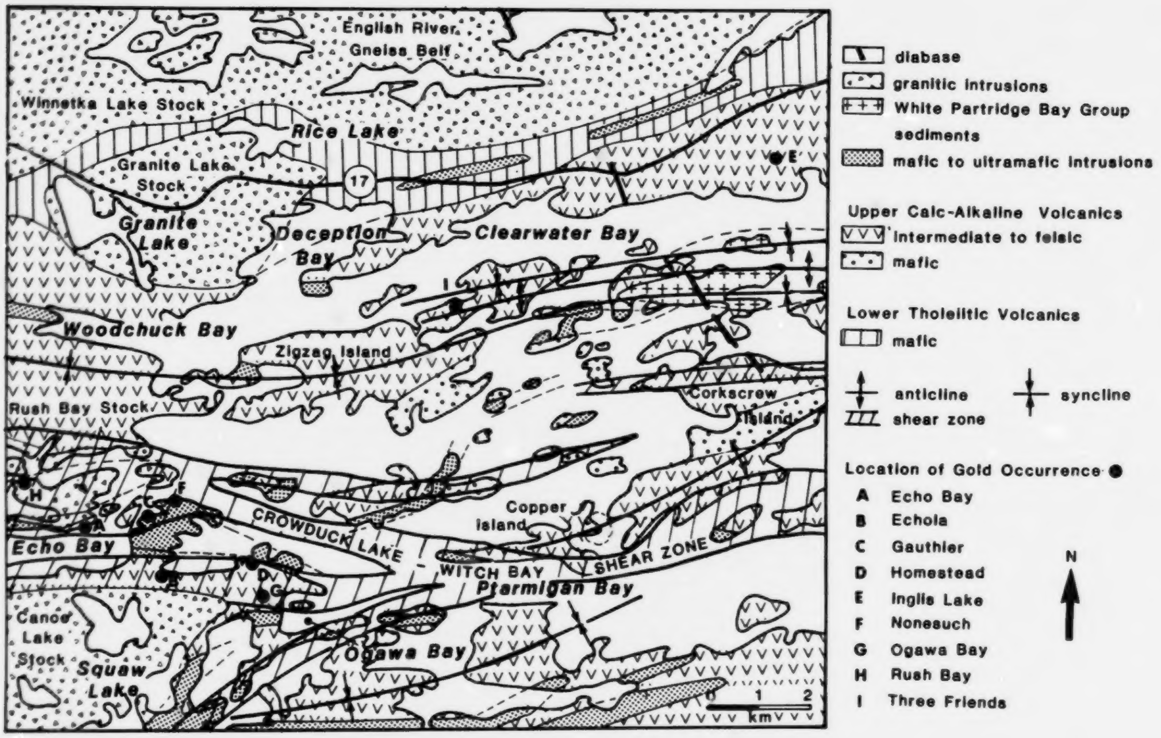

English River Gneiss Belt
Winnetka Lake Stock
Rice Lake
Granite Lake Stock
17
Granite Lake
Deception Bay
Clearwater Bay
Woodchuck Bay
Zigzag Island
Rush Bay Stock
Corkscrew Island
Echo Bay
Crowduck Lake
Copper Island
Witch Bay
Shear Zone
Ptarmigan Bay
Canoe Lake Stock
Squaw Lake
Ogawa Bay
0 1 2 km
diabase
granitic intrusions
White Partridge Bay Group sediments
mafic to ultramafic intrusions
Upper Calc-Alkaline Volcanics
intermediate to felsic
mafic
Lower Tholeiitic Volcanics
mafic
anticline
syncline
shear zone
Location of Gold Occurrence ●
A Echo Bay
B Echola
C Gauthier
D Homestead
E Inglis Lake
F Nonesuch
G Ogawa Bay
H Rush Bay
I Three Friends
N

Figure 007.1. *Generalized geological map of the Clearwater Bay Area, Lake of the Woods.*

In 1970, Noranda Exploration Company conducted ground geophysical surveys and trenching in the Squaw Lake area. This work was followed up by an induced polarization survey and diamond drilling by Kerr Addison Mines Limited in 1972.

In 1966, Selco Exploration Company Limited diamond drilled three holes north of Rush Bay.

GENERAL GEOLOGY

Early mapping of the eastern half of the area was by Thomson (1937), and the western half by Greer (1931), both at the 1 inch to 1 mile (1:63 360) scale. More recent mapping in the surrounding area has been done to the east by the author (Ayer *et al.* 1986), to the south by Davies (1983), and to the west by Davies (1965), all at a 1 inch to 1/4 mile (1:15 840) scale.

A generalized geological map of the area is presented in Figure 007.1. All bedrock is of Archean age with the exception of an Early Proterozoic diabase dike. In general, stratigraphy and structures in the area have an overall east-west trend. Interpretation of stratigraphy is also based on similarities and lithological associations observed in mapping to the east (Ayer *et al.* 1985, 1986).

The oldest stratigraphic unit, the Lower Mafic Unit, occurs in the northern part of the map area. It is up to 1 km thick and consists of pillowed to massive tholeiitic basaltic flows. Plagioclase-phyric basaltic flows, with phenocrysts up to 1 cm (leopard rock), occur in the west along Highway 17 and Deception Bay. They also occur locally near the top of the Lower Mafic Unit in the Bigstone Bay and Rat Portage Bay areas (Ayer *et al.* 1985, 1986).

South of, and conformably overlying, the Lower Mafic Unit is a compositionally and texturally diverse unit of calc-alkalic metavolcanics. They underlie much of the map area and range in composition from basaltic andesites to rhyolites. In the Clearwater Bay area, they consist predominantly of debris flows with some minor, massive to pillowed flows. The debris flows consist of coarse, heterolithic, angular, volcanic fragments in a fine-grained plagioclase crystal-rich matrix. Locally, these grade into fine-grained crystal tuffs and/or thinly laminated siltstones. The central part of the map area is predominantly underlain by pillowed flows with some subordinate debris flows and pillow breccias. The flows are commonly amygdaloidal and, in general, the more siliceous andesitic (or dacitic) flows form large pillows up to 10 m long by 4 m thick. These are typically plagioclase porphyritic with thick, light-coloured selvages. The more mafic flows have smaller pillows, are typically aphyric, have thin dark green selvages, and are locally variolitic.

Intercalated felsic units have abundant quartz phenocrysts and locally lithic and/or pumaceous fragments. Most of these are interpreted to be primary (i.e. unreworked) pyroclastic deposits. Locally within the felsic units are thin, very fine grained cherty beds. Locally thin beds of fine-grained wackes, mudstones, siliceous siltstones and chert-sulphide ironstone occur within the calc-alkalic volcanic sequence.

Mafic sills intrude both the tholeiitic and calc-alkalic metavolcanics and the interflow metasediments.

Locally the sills display differentiation, with ultramafic phases at the base grading upwards into gabbro or leucogabbro at the top. Other synvolcanic intrusions are fine-grained intermediate to felsic dikes, sills, or small stocks, which are commonly plagioclase and/or quartz porphyritic.

Metasediments of the White Partridge Bay Group are interpreted (Ayer and Gil 1986) to unconformably overlie the calc-alkalic metavolcanics and the synvolcanic intrusions. In the map area they consist predominantly of fine-grained, well-bedded and normally graded wackes and mudstones. Some intercalated conglomerate beds, up to 1 m thick, occur along the northern side of Corkscrew Island. These conglomerates have clasts of angular wacke and mudstone rip-ups in a fine-grained clastic matrix. An unusual lithology occurs at the base of the White Partridge Bay Group along its southernmost exposures. The unit consists of fine-grained, massive to bedded, felsic rock with rounded quartz eyes, locally with mudstone-siliceous siltstone interbeds.

Several ages of granitic intrusion are apparent in the area. The oldest are pretectonic tonalitic to granodiorite gneisses of the English River Subprovince in the north. Throughout most of the map area the contact between these gneisses and the metavolcanics of the Wabigoon Subprovince, to the south, is abrupt. In the western part of the map area, the volcanic rocks are intruded by the Winnetaka Lake Stock. This intrusion consists of medium-grained equigranular quartz monzodiorite to granodiorite with hornblende as the dominant ferromagnesian mineral. Toward the east, north of Rice Lake, it grades into coarse-grained hornblende diorite. Toward the north, the stock grades into gneisses of granodioritic to tonalitic composition. In general the stock has a well developed penetrative foliation similar to the regional fabric, and is thus interpreted to be a pretectonic intrusion.

The Granite Lake Stock, occurring totally within the metavolcanics, is enclosed by a thin septum of mafic metavolcanic to the north. It consists of megacrystic granodiorite with coarse-grained, subhedral to euhedral alkali-feldspar phenocrysts up to 3 cm in size in a medium-grained, equigranular groundmass, with biotite as the dominant ferromagnesian mineral. A weakly developed foliation tends to follow the contacts of the intrusion, thus indicating a syn- to late-tectonic origin for the stock.

The Rush Bay Stock occurs within the Crowduck Lake-Witch Bay Shear Zone. It is a medium-grained, porphyritic, quartz monzo-diorite with alkali feldspar phenocrysts up to 3 cm long. The phenocrysts consist of potassium feldspar cores mantled with plagioclase rims. A fine-grained felsite, which can locally be seen to grade into the porphyritic unit, occurs marginal to the intrusion. The margins of the stock are highly sheared but the core is only weakly deformed, which indicates a pre- to syntectonic origin.

The Canoe Lake Stock is medium-grained, equigranular to quartz-porphyritic tonalite. Locally, anhedral to euhedral quartz and plagioclase phenocrysts occur up to 1 cm in size. The intrusion is transected by felsic porphyry dikes which also occur in the surrounding country rock. The centre of the intrusion is unstrained, with strain increasing towards its margins. The stock has been interpreted by Campbell (1973) as a shallow syntectonic pluton.

Metamorphism is greenschist facies throughout most of the map area but rises to amphibolite facies in the north, within several kilometres of the English River Subprovince boundary.

STRUCTURAL GEOLOGY

Fold axes have been identified, to a large extent, on the basis of reversals in facing directions. A synclinal axis trends easterly to northeasterly across the central part of the map area. A parallel anticline and syncline are well defined to the north of this syncline, in the White Partridge Bay Group, and can be extended at least half way across the map area with confidence.

A northeast-trending anticline can be traced across Copper Island and is interpreted to extend across Corkscrew Island, where it is continuous with an anticline identified on the eastern side of Corkscrew Island in 1985 (Ayer *et al.* 1986). A parallel syncline can be traced southwestward from Ptarmigan Bay to the Canoe Lake Stock.

A major zone of ductile deformation, identified as the Crowduck Lake-Witch Bay Shear Zone (CDL-WBSZ), trends easterly across the southern part of the map area. This structure consists of alternating zones of highly and moderately strained rock, which collectively attain widths of up to several kilometres; many of these zones are under water. The amount of deformation is typically in proportion to the competency of the original lithologies. Massive intrusions are typically only moderately foliated while fine-grained metavolcanics and metasediments commonly have very strongly developed, planar schistosity. Alteration, consisting of calcium and/or iron carbonatization, is widespread. Zones of silicification (both pervasive and in the form of quartz veining) and sulphide enrichment are less widespread than carbonatization, and are commonly associated with gold mineralization. Several splays occur off the main shear zone. Two of these are spatially related to the Canoe Lake Stock; one occurs along its northern and the other along its eastern margin.

ECONOMIC GEOLOGY

Many of the gold occurrences in the map area are closely related to the major shear zones. Four of these, the Echo Bay (A), the Gauthier (C), the Nonesuch (F), and the Rush Bay (H) Occurrences fall within the CDL-WBSZ, marginal to the Rush Bay Stock. At the Echo Bay Occurrence (A), an old adit, about 22 m long, trends across the strike of the schistosity. The rock consists of highly sheared intermediate metavolcanics with localized silicified to sulphide enriched sections. Locally, small quartz veins, up to 20 cm wide, contain minor pyrite. Channel samples, collected by Tasu Resources Limited in 1980 (RGFK), indicated the best assay section is 0.17 ounce gold per ton over 1.8 m from the adit, and 0.106 ounce gold per ton over 4.4 m from a trench above the adit. Channel samples from trenches on the Gauthier Occurrence (C), by Sylvanite Mines Limited in 1945 (RGFK), indicate values of 0.13 ounce gold per ton over 4 m and erratic values in other trenches with a maximum of 0.30 ounce gold per ton over 90 cm.

Three occurrences are within a splay off the main shear zone which trends along the northern margin of the Canoe Lake Stock. They are the Echola (B), the Homestead (D), and the Ogawa Bay (G) Occurrences. The shafts at the Echola (B) and Homestead (D) Occurrences are in carbonatized and sheared felsic metavolcanics with minor quartz veinlets and disseminated pyrite. The shaft and trenches at the Ogawa Bay Occurrence (G) are in a large gossan zone about 30 m wide with disseminated to massive pyrite and sugary quartz in sheared intermediate metavolcanics cut by felsic porphyry dikes.

Several vein-type gold occurrences are located in the northern part of the area around Clearwater Bay. In general, these are in narrow east-northeast-trending shear zones in intermediate metavolcanics with minor carbonatization and disseminated pyrite and/or arsenopyrite. The Three Friends Occurrence (I) consists of four shafts, an adit, and numerous pits and trenches on a shear zone exposed intermittently over a strike length of about 1.5 km. The zone is up to several metres in width, and the associated quartz vein is up to 50 cm wide. The quartz vein contains variable amounts of carbonate, muscovite, pyrite, arsenopyrite, and galena. Gold values, reported by Denison Mines Limited in 1981 (RGFK), are low, ranging from 0.02 to 0.05 ounce gold per ton. The quartz vein on the Inglis Lake Occurrence, with a maximum width of 70 cm, is exposed in numerous trenches over a strike length of 100 m. The vein contains carbonate, block tourmaline, and up to 5 percent pyrite. Grab samples collected by members of the field party during the field season indicate values as great as 0.60 ounce gold per ton (Geoscience Laboratories, Ontario Geological Survey, Toronto).

RECOMMENDATIONS

The area is considered to have good potential for economic concentrations of gold. The areas of highest potential are considered to be within the ductile shear zones in the southern part of the map area. Particular attention should be paid to areas in which there is high competency contrast between lithologies, to splays off the main shear system, and to points of abrupt changes in the trend of shear zones. Such sites may have formed channelways for gold-bearing hydrothermal fluids.

An example of the above mechanism may be present in the southern part of Corkscrew Island. There, the shear zones change in orientation from easterly to northeasterly. At the locus of this change on the extreme southwestern tip of the island are east-trending breccia zones up to tens-of-metres thick. The breccias consist of angular altered volcanic fragments in a network of medium- to coarse-grained iron carbonate, quartz, and pyrite. Two grab samples of this breccia, taken by members of the field party, one from the southwestern tip of Corkscrew Island, the other from a small island between the southern tips of Corkscrew and Copper Islands, returned values of 1235 and 540 ppb gold, respectively (Ontario Geoscience Laboratories, Ontario Geological Survey, Toronto).

ACKNOWLEDGMENTS

Michael Flanagan, of Homestake Mineral Development Company, is thanked for access to company airborne geophysical data not filed for assessment, and for helpful discussions on the geology of the map area.

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008. Geology of the Northwest Angle Inlet Area, Lake of the Woods, District of Kenora

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Field investigations implemented in 1986 represent the initial phase of a two-year geological mapping project in the southwestern part of Lake of the Woods. An area of about 250 km^2 was mapped at a scale of 1:15 840; this area is bounded by Latitudes 49°30′N and the U.S.A. (Minnesota) border (approximate Latitude 49°22′N) and Longitude 94°56′W and the Manitoba border (Longitude 95°09′W). The Town of Kenora is 60 km northwest of the centre of the map area. In 1987, mapping will progress east from the present map area.

Except for areas bounded by Shoal Lake and Lake of the Woods, access in the map area is poor. Traversing in the central portion of the map area was facilitated, somewhat, by establishing a network of footpaths along mainly disused winter logging roads. A helicopter was required in the southwestern part of the map area as access was hampered by floating bog along the shoreline of Northwest Angle Inlet.

Outcrop exposures are unevenly distributed in the map area, comprising less than 5 percent of the western half of the area and increasing in abundance to the east. Except for areas underlain by granitic rocks, outcrops in the bush generally are poorly exposed due to a ubiquitous, although uneven, veneer of sandy till.

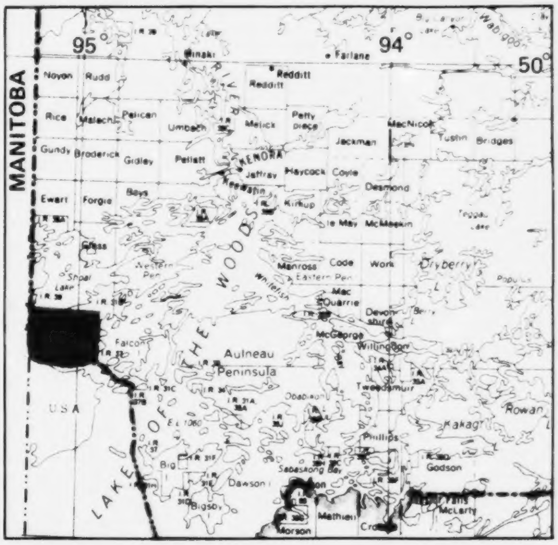
MINERAL EXPLORATION

The following information has been obtained from the assessment files of the Resident Geologist's Office, Ontario Ministry of Northern Development and Mines, Kenora.

Records of gold exploration are limited to two properties (Popham-Byberg, Black Fox Islands) in the southwestern part of Shoal Lake. Davies (1978) summarized exploration activity carried out from the 1930s to the 1950s at the Popham-Byberg Occurrence (also known as the Magnet Point Syndicate Group) at Calm Bay (Location 1, Figure 008.1). Since then only limited work, chiefly by A. Mickelson of Winnipeg, has been done on this occurrence. Records of exploration activity at the Black Fox Islands (Location 2, Figure 008.1) are sparse and limited to reports of minor trenching in the early 1900s.

Base-metal (zinc, copper) exploration was carried out in 1975 by Hudson Bay Exploration and Development Company Limited (HBED) in the central and eastern part of the map area. HBED reported results from six drillholes which tested electromagnetic anomalies discovered as a result of a 1972 airborne electromagnetic survey (not on file).

At the time of writing (September 1986), there are no claims in good standing in the map area.


95°
94°
50°
MANITOBA
Minaki
Farlane
Redditt
Redditt
Wabigoon
Noyon
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Rice
Malachi
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Umbach
Melick
Pettypiece
MacNicol
Tustin
Bridges
Jackman
Gundy
Broderick
Gidley
Pellatt
KENORA
Jaffray
Haycock
Coyle
Keewatin
Desmond
Ewart
Forgie
Boys
Kirkup
Teggau Lake
le May
McMeekin
Glass
Western Pen
Shoal Lake
LAKE OF THE WOODS
Manross
Code
Work
Dryberry L
Eastern Pen
Whitefish
Populus
Mac Quarrie
Devonshire
Berry L
McGeorge
Willingdon
Falcon
Aulneau Peninsula
Tweedsmuir
Obabikon
Rowan
U.S.A.
Kakagi
Phillips
Big
Sabaskong Bay
Godson
Dawson
Bigsby
Mathieu
Morson
McLarty
Crozier

LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

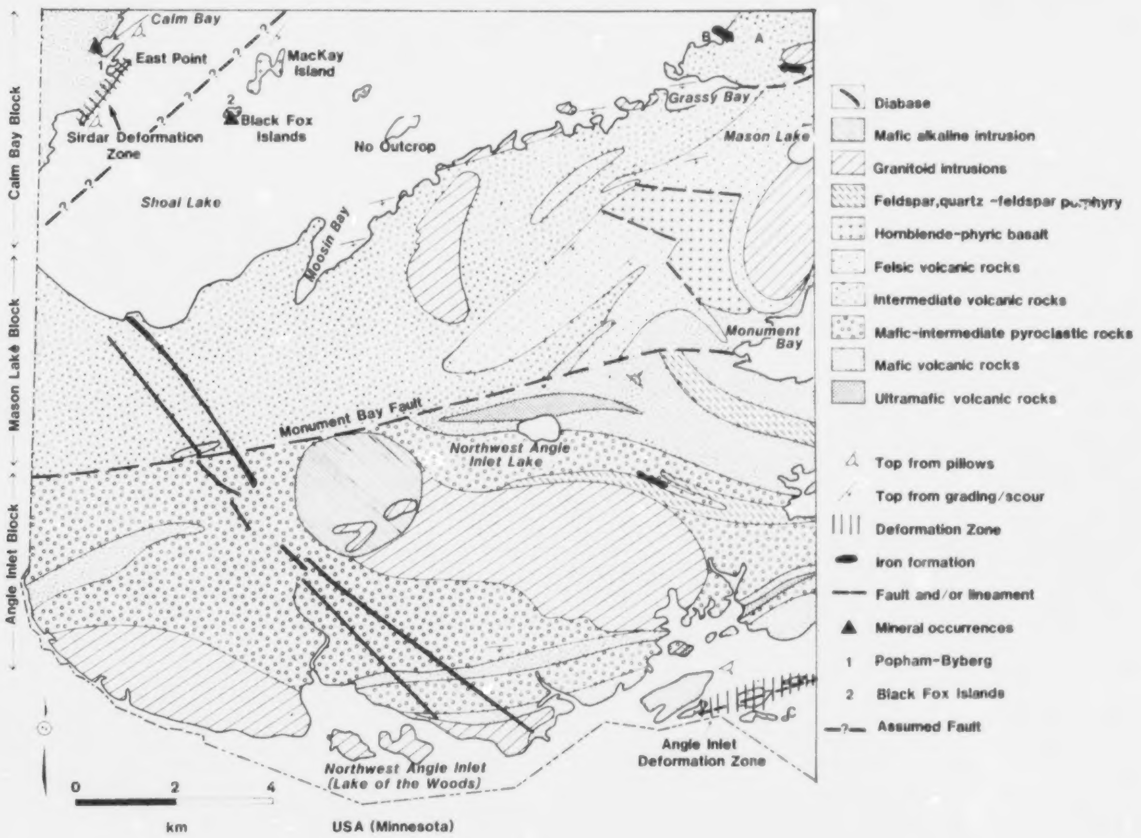
Calm Bay
East Point
MacKay Island
Black Fox Islands
Sirdar Deformation Zone
No Outcrop
Shoal Lake
Moosin Bay
Grassy Bay
Mason Lake
Monument Bay
Monument Bay Fault
Northwest Angle Inlet Lake
Angle Inlet Deformation Zone
Northwest Angle Inlet (Lake of the Woods)
USA (Minnesota)
MANITOBA
Calm Bay Block
Mason Lake Block
Angle Inlet Block
A
B
1
2
0
2
4
km
Diabase
Mafic alkaline intrusion
Granitoid intrusions
Feldspar,quartz -feldspar porphyry
Hornblende-phyric basalt
Felsic volcanic rocks
Intermediate volcanic rocks
Mafic-intermediate pyroclastic rocks
Mafic volcanic rocks
Ultramafic volcanic rocks
Top from pillows
Top from grading/scour
Deformation Zone
Iron formation
Fault and/or lineament
Mineral occurrences
1 Popham-Byberg
2 Black Fox Islands
Assumed Fault

Figure 008.1. *Generalized geological map of the Northwest Angle Inlet Area, District of Kenora.*

GENERAL GEOLOGY

Little was known about the geology of the Northwest Angle Inlet area prior to the present study. Parts of the present map area are included in Lawson (1885) and Greer (1931). The map area adjoins the Bag Bay map sheet of the Ontario Geological Survey (Davies 1982) to the north, and the Southeast Manitoba sheet of the Manitoba Department of Energy, Mines and Natural Resources to the west (Lamb 1975).

All bedrock in the map area is inferred to be Archean in age, with the exception of northwest-trending Early Proterozoic diabase dikes.

In the present study, the Northwest Angle Inlet map area has been subdivided into three subareas or structural blocks: the Calm Bay Block (CBB) in the northwest, the Mason Lake Block (MLB) in the north, and the Angle Inlet Block (AIB) in the south (Figure 008.1). Each block is lithologically distinct. The contact between the CBB and MLB was not observed because it is beneath Shoal Lake between Calm Bay and Mackey Island. This contact is inferred to be a fault, on the basis of contrasting lithologies and metamorphic grade between the CBB and MLB. The MLB-AIB boundary is the east-trending Monument Bay Fault Zone (Figure 008.1). The relative ages of the three blocks are not known with any certainty; however, the dominantly felsic composition of the MLB, and the presence of hornblende-phyric mafic metavolcanics in the MLB (discussed below), suggests that the MLB is younger than the dominantly mafic AIB. Correlations between blocks have not been attempted. Supracrustal lithologies of these three blocks are described separately below.

CALM BAY BLOCK

The CBB is underlain by northeast-trending mafic metavolcanics, gabbros, and minor quartz-feldspar porphyries. Mafic metavolcanics are nonvesicular flows, predominantly pillowed; a compound flow with a massive base and pillowed top occupies the peninsula on the eastern side of Calm Bay. The majority of mafic flows in the western CBB contain 0.5 to 2.5 cm diameter plagioclase phenocrysts in a fine-grained light green groundmass. These light green flows (Mg-tholeiites?) contrast with darker green mafic aphyric pillowed flows (Fe-tholeiites?) which comprise the northeast-trending ridge of East Point.

Gabbros occur as conformable bodies, up to 100 m thick. They are fine- to medium-grained equigranular to inequigranular rocks; colour indices range from 20 to 80. These gabbros are interpreted to be synvolcanic sills; however, finer grained varieties may be thick massive flows. Quartz-feldspar porphyry dikes and sills, 1 to 10 m in width, intrude the mafic rocks of the CBB.

ANGLE INLET BLOCK

The AIB is underlain predominantly by east-trending mafic to intermediate metavolcanics, with lesser ultramafic and felsic metavolcanics and minor metasediments. Mafic to intermediate metavolcanics are predominantly well-bedded pyroclastic deposits. Heterolithic tuff breccia and lapilli-tuff dominate, tuff occurs locally. Clasts are mafic to felsic; mafic to intermediate clasts dominate. Clasts are texturally diverse; many are plagioclase and/or hornblende-phyric. These pyroclastic rocks are interpreted, on the basis of primary structures, to be debris flows and lahars, many of which have been reworked to some degree. Along Northwest Angle Inlet, nonvesicular, massive and pillowed mafic flows comprise two mappable units interbedded with the pyroclastic deposits. Aphyric flows comprise the more northerly of these two flow units; the southern unit is composed of plagioclase-phyric flows with 15 to 20 percent, 1 to 5 mm long plagioclase phenocrysts.

Ultramafic flows are interlayered with mafic flows in two mappable units, north of Northwest Angle Inlet Lake and in the southeastern part of the map area. Both units comprise nonvesicular, nonmagnetic, light to medium green pillowed and massive aphyric flows. These rocks are composed of light green (tremolitic?) amphibole with little or no plagioclase. Individual flows are 2 to 10 m thick; flow contacts are marked by carbonatized rubbley flow tops and bases. They are interpreted to be metamorphosed basaltic komatiites.

Felsic metavolcanics in the AIB include thin-bedded tuffs southeast of Northwest Angle Inlet Lake and tuff breccia, lapilli-tuff, tuff and flows (?) in the southeastern part of the map area.

Epiclastic metasediments overlie plagioclase-phyric mafic metavolcanics in the southeastern part of the map area. Here, A to E Bouma sequences are defined by 1 to 2 m thick muscovite-porphyroblastic quartz-plagioclase-biotite schists interbedded with 5 to 10 cm thick biotite-rich layers. Thinly bedded epiclastic and chemical metasediments occur in a 10 to 20 m thick unit associated with felsic tuffs southeast of Northwest Angle Inlet Lake. Sulphide facies iron formation forms an integral part of this unit.

MASON LAKE BLOCK

The MLB is dominated by northeast-trending intermediate and felsic metavolcanics with lesser mafic metavolcanics and metasediments. Distinctive hornblendephyric mafic metavolcanics underlie two separate areas within the MLB.

Intermediate metavolcanics are predominantly pyroclastic deposits with lesser flows and synvolcanic sills. Pyroclastic deposits are composed of heterolithic tuff breccia and lapilli tuff, interpreted, on the basis of primary structures, to be metamorphosed debris flows and lahars. Lenses of intermediate volcanic conglomerates within felsic metavolcanics, southwest of Mason Lake, may represent fluvial deposits. A massive, intermediate to felsic flow, northeast of Grassy Bay, Shoal Lake, is associated with sulphide facies iron formation.

Felsic metavolcanics, which underlie approximately 50 percent of the eastern half of the MLB, comprise a northeastward thickening wedge of dominantly pyroclastic deposits. Heterolithic and monolithic tuff breccia and lapilli-tuff, and thickly and thinly bedded tuff, are the principal components. Most are plagioclase± quartz-phyric, characteristically containing 15 to 30 percent, 2 to 3 mm long, equant plagioclase phenocrysts. Many of the heterolithic units are interpreted, on the basis of primary features, to be debris flows and lahars; fluvial channel-fill deposits occur locally. Units of monolithic tuff breccia and lapilli-tuff and thickly bedded tuff, some of which contain pumice clasts, are interpreted to be metamorphosed pyroclastic flows. Accretionary lapilli in felsic tuff, northwest of Mason Lake, indicate subaerial or shallow water volcanism in that area (Moore and Peck 1962).

Thinly bedded siliceous siltstones are interbedded with intermediate and felsic metavolcanics along the southern shore of Shoal Lake, and in an east-trending unit north of Grassy Bay.

Distinctive hornblende-phyric (after clinopyroxene?) mafic and intermediate metavolcanics underlie two separate areas within the MLB. At Mackey and surrounding islands on Shoal Lake, massive units contain 20 to 30 percent, 1 cm long, euhedral hornblende phenocrysts in a fine-grained mafic groundmass. These massive flows(?)/sills(?) are overlain to the southeast by monolithic tuff breccia and thinly bedded tuff. Tuff breccia units are composed dominantly of clasts which resemble the massive units to the northwest. However, some units comprise clasts of highly vesicular (20 to 30 percent calcite-filled amygdules) hornblende-plagioclase-phyric basalt. Tuffs generally contain minor hornblende crystals and locally exhibit bomb-sag structures, indicative of near-vent subaerial to shallow water volcanism. Hornblende-phyric metavolcanics also occur southwest of Mason Lake in a fault-bounded block within felsic metavolcanics. Here, highly vesicular (up to 40 percent calcite-filled amygdules) mafic flows, with vaguely defined pillow-like forms, are interpreted to have erupted subaerially as pahoehoe flows. Many of these flows have nonvesicular massive hornblende-cumulate bases. Clasts of these hornblende-phyric basalts occur in heterolithic felsic debris flows to the northeast. Several hornblende-phyric mafic sills (1 to 20 m wide) intrude intermediate volcanic rocks south of Shoal Lake. Similar hornblende-phyric basalts have been documented at Gibi Lake on the eastern side of Lake of the Woods (Trowell, in press) and at Sunshine Lake south of Dryden (Blackburn 1981). The mineralogy of these basalts and chemical analyses (Trowell, in press; Blackburn 1982; Teal 1979) indicate an alkalic affinity. This change in geochemistry chronicles on evolutionary change in volcanism which may characterize the culmination of volcanic activity in many Archaean volcanoes (cf. Hallberg 1986).

INTRUSIVE ROCKS

All three structural blocks contain metamorphosed intermediate to felsic plagioclase, quartz-plagioclase and/or quartz porphyry sills, many of which may be synvolcanic. These sills range from <1 m to 1 km thick and have been traced along strike for up to 6 km. The most prominent such sills occur in the northeastern part of the AIB.

The MLB and AIB are intruded by syn- to post-tectonic granitic plutons. All are composed of non- to weakly foliated, medium- to coarse-grained, equigranular to megacrystic (microcline), hornblende-biotite granite to granodiorite with foliated hornblende diorite, quartz diorite, or granodiorite margins. Foliations are parallel to the pluton margins, indicative of development during emplacement. These plutons have 0.25 to 1 km wide epidote-hornblende hornfels contact aureoles.

A poorly exposed 2.6 km diameter plug of uniform fine- to medium-grained equigranular magnetite-biotite hornblendite is a striking feature of the central part of the map area. This plug has a much more extensive aeromagnetic expression (6 km in diameter) (GSC-ODM 1967) indicating that the exposed limits represent the top of a much larger intrusion. Several rafts of shallow dipping (20° to 40°) foliated granodiorite occur within the outcrop limits of the hornblendite.

Early Proterozoic northwest-trending diabase dikes intrude the AIB and MLB, of which the two most prominent and continuous occur in the western map area. These dikes range from <1 m to 250 m thick, are aphanitic to coarse-grained, diabasic-textured, and have well defined chill margins. Discontinuous phase layering parallels the dike contacts. Epidote-hornblende hornfels contact aureoles have developed in country rocks adjacent to these diabase dikes.

STRUCTURE AND METAMORPHISM

Reliable facing indicators are poorly preserved in the map area. However, those that are preserved, with the exception of north-facing pillow basalts west of Monument Bay in AIB, indicate south-facing directions in all three structural blocks.

Most supracrustal lithologies in the map area have a well developed foliation which trends east to northeast, except where deflected in the vicinity of granitic plutons. The intensity of fabric development is heterogeneous and may be absent, as in the case of some felsic metavolcanics southwest of Mason Lake. Foliation is generally parallel, or near-parallel, to layering. However, southwest of Mason Lake, foliation has developed locally at high angles to bedding in felsic tuffs at minor (?) fold noses. Shallow (30° to 50°) dips, which characterize regional foliation in the southern part of Monument Bay and in the southeastern part of the map area, are the result of reorientation of an original steeply dipping foliation (W.C. Brisbin, Professor, Department of Geological Sciences, University of Manitoba, Winnipeg, personal communication, 1986).

The most prominent fault in the map area is the 50 to 200 m wide east-trending Monument Bay Fault Zone which separates the felsic MLB from the mafic AIB. This fault is poorly exposed, being marked by swamps along most of its length. Where exposed, lithologies within this fault zone are locally sheared and carbonatized. Secondary fabrics (crenulation cleavage, fracture cleavage) have developed locally near the eastern end of the fault. Relative movement on the Monument Bay Fault Zone is not known, however a component of dextral strike slip movement is indicated by the bending of lithologies to the south and west of Monument Bay.

A 200 m wide zone of ductile deformation (Angle Inlet Deformation Zone) has affected the felsic metavolcanics in the southeastern map area. Deformation in this zone is characterized by the heterogeneous development of mylonite and protomylonite.

A northeast-trending shear zone coincident with pillowed mafic flows in the CBB has been interpreted to be the southwestern extension of the Sirdar Deformation Zone (Smith 1986).

Inferred faults, which bound hornblende-phyric metavolcanics southwest of Mason Lake, may represent extension-related rifting which preceded and/or was synchronous with eruption of these basalts.

Greenschist facies assemblages characterize lithologies within the CBB; all other lithologies in the map area have been metamorphosed to amphibolite facies grade. Minor local retrograde metamorphism has developed in amphibolite facies rocks adjacent to quartz veins and pegmatite dikes. Hornblende porphyroblasts have developed locally in mafic and intermediate volcanic rocks; porphyroblast development often is spatially related to faults. This is especially evident at the eastern end of the Monument Bay Fault Zone. Epidote-hornblende hornfels contact aureoles have developed in country rocks adjacent to granite plutons and diabase dikes. Migmatite occurs locally in the northern contact aureole of the oval-shaped granite which occurs immediately north of Northwest Angle Inlet. Felsic metavolcanics in the southeastern map area have been intensely recrystallized, often to the point of obscuring primary fabric. This high degree of recrystallization may be related to granitoid rocks south of the map area, possibly the western extension of the Sabaskong Batholith.

ECONOMIC GEOLOGY

The dearth of known mineral occurrences should not be allowed to deter further exploration in the Northwest Angle Inlet area. This is an underexplored area, which contains several distinct geological environments, any of which has the potential to host gold or base metal deposits.

Base-metal (zinc, copper) exploration should focus on felsic metavolcanics in the MLB and AIB. In particular, two areas are deemed especially favourable; both are proximal to vent areas in comprising coarse pyroclastic deposits and flows. At Location A (Figure 008.1) a massive, locally brecciated, intermediate-felsic flow is associated with sulphide facies iron formation (exhalative?). Coarse felsic pyroclastic deposits, with 5 to 10 percent disseminated pyrite, occur in the same area (Location B, Figure 008.1). In the southeastern part of the map area, coarse felsic pyroclastic deposits and possible felsic flows are associated with widespread hydrothermal alteration characterized by hornblende-chlorite-epidote veining. Where alteration is more intense, as at Location C (Figure 008.1), hydrothermal breccias have developed whereby hornblende-chlorite-epidote forms the matrix to subangular felsic clasts. This style of alteration is similar to footwall alteration zones associated with many Archean massive sulphide deposits.

The most favourable environments for gold exploration include: a) shear zones associated with major faults and deformation zones; b) intermediate and felsic porphyry sills, c) subaerial metavolcanics; d) sulphide facies iron formation; and e) metavolcanic-metasediment contact zones.

The fault and deformation zones which have potential for hosting gold deposits are the southwestern extension of the Sirdar Deformation Zone in the CBB, the Monument Bay Fault Zone, and the Angle Inlet Deformation Zone. The Sirdar Deformation Zone is parallel to the Duport Deformation Zone which hosts the Duport Mine, approximately 10 km northeast of Calm Bay. At least one gold occurrence (Mikado Reef Mine) occurs in the Sirdar Deformation Zone, northeast of the present map area (Smith 1986; Davies 1982). Focusing of hydrothermal fluids by the Monument Bay Fault Zone is indicated by carbonatization of sheared mafic and ultramafic metavolcanics and hornblende porphyroblast development. Pyrite occurs in isolated pockets and discrete zones within the Angle Inlet Deformation Zone. Prospecting in these fault and deformation zones should focus on delineation of subsidiary fault splays, sulphide mineral zones, alteration zones (carbonatization, silicification), areas of quartz veins, and zones of dilatancy, the latter perhaps related to flexures of the main structures.

At Calm Bay, gold is associated with quartz veins which intrude pyritic quartz-feldspar porphyry sills. Similar sills occur throughout the map area and warrant exploration for gold. In the Grassy Bay area of Shoal Lake, sulphide mineralization is associated with several of these porphyry sills.

Possible subaerial volcanic rocks west and southwest of Mason Lake should be explored for metamorphosed epithermal gold deposits. Exploration in this area should focus on the identification of metamorphosed epithermal alteration zones (cf. Buchanan 1981) and discordant structural zones. The boundaries of the hornblende-phyric basalts are prime exploration targets in this regard. If these boundaries are synvolcanic rifts they would have provided excellent channelways for migration of hydrothermal fluids.

Two bands of sulphide facies iron formation should be prospected for gold. North of Grassy Bay, a 5 to 10 m wide band of thinly laminated cherty iron formation is associated with mafic and intermediate-felsic metavolcanics. Southeast of Northwest Angle Inlet Lake a 5 to 10 m wide sulphide iron formation is associated with epiclastic metasediments and felsic metavolcanics.

Epiclastic sedimentation, sulphide mineralization, local silicification, and garnet amphibole veining and alteration characterize the transition from mafic metavolcanics to felsic metavolcanics along the northern shore of Northwest Angle Inlet in the southeastern map area. This transition zone appears to have been favourable for the focusing of hydrothermal fluids.

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009. Kakagi Lake-Rowan Lake Regional Geology, District of Kenora

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INTRODUCTION

Field work completed during the Summer of 1986 is the third year of a project designed to provide a regional synthesis of geological data in the Gibi-Kakagi-Rowan Lakes area of northwestern Ontario. Descriptions of the previous field work are available in the 1984 and 1985 Summary of Field Work volumes published by the Ontario Geological Survey (Johns 1984, 1985). The study area, outlined on the location map, has been mapped previously as follows: the Rowan Lake area (Kaye 1973), the Cedartree Lake area (Davies and Morin 1976), the Gibi Lake area (Trowell, in press), the Schistose Lake area (Edwards 1980), the Kakagi Lake area (Kaye 1981), the Straw Lake area (Edwards 1983), and the Long Bay-Lobstick Bay area (Johns and Richey 1982; Johns and Davison 1983; Johns, Good, and Davison 1984).

During the 1986 field season, the southern and eastern parts of the Rowan Lake area were examined (*see* Figure 009.1). Rowan Lake is 80 km north of Fort Frances and is accessible by float-equipped aircraft. Access within the area is provided by portages between Rowan, Hill, Fog, and Lawrence Lakes. In conjunction with this synoptic study, semi-detailed mapping was carried out between Rowan and Lawrence Lakes and Ajax and Heifer Lakes (*see* Chivers, this volume).

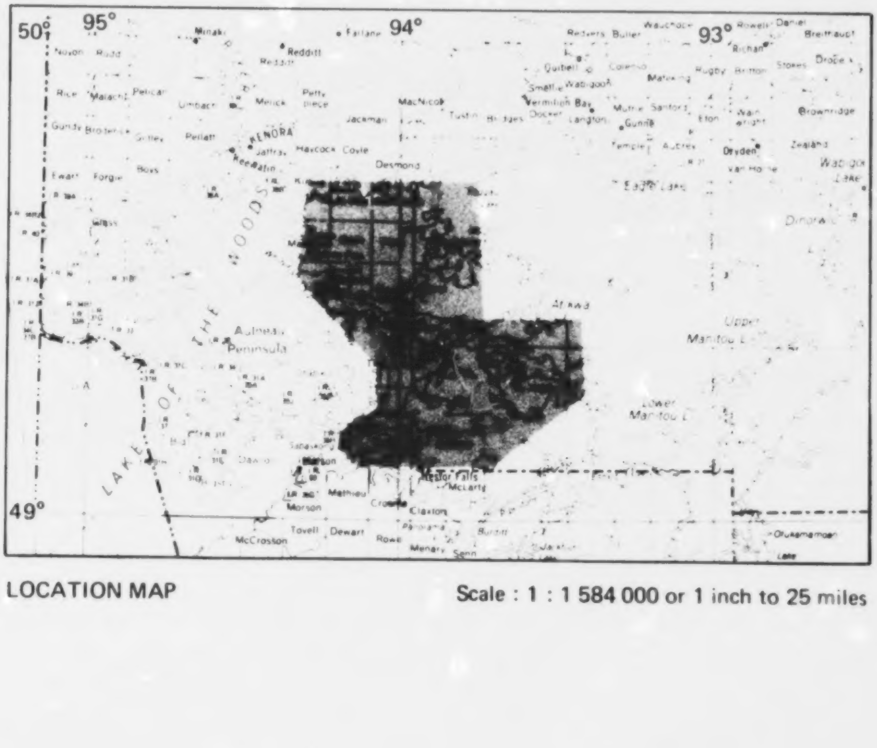
MINERAL EXPLORATION

Gold remains the metal of main interest in the Rowan Lake area. Previous exploration has been described in past volumes of "Report of Activities, Regional and Resident Geologists" by the Ontario Geological Survey. Exploration for gold in the Rowan Lake area is currently being carried out by Nuinsco Resources Limited on their Monte Cristo Deposit.

GENERAL GEOLOGY

The study area is situated at the western edge of the Wabigoon Subprovince between Lake of the Woods and the Savant Lake-Crow Lake area (Trowell *et al.* 1980). Trowell *et al.* (1980, Figure 2) subdivided the supracrustal rocks in the Rowan Lake area into two sequences: mafic to felsic flows and pyroclastics (Rowan Lake volcanics) and an overlying sequence of "middle/upper" mafic flows (Brooks Lake volcanics). The volcanic rocks north of the Nolan Lake Stock were previously assigned to the Rowan Lake volcanics and the Brooks Lake volcanics were south and east of the stock (Trowell *et al.* 1980). As work proceeded on this project in the Rowan Lake area, the previous subdivision was not found to be valid. The mafic flows, except where noted, appear to be correlatable. The division of these flows into the Rowan Lake and Brooks Lake volcanics is not based on any discernable textural or structural basis and are here termed the Rowan Lake volcanics.

Figure 009.1 outlines the stratigraphy of the Rowan Lake area developed during the course of the 1986 field season. Two stratigraphically and structur-



LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

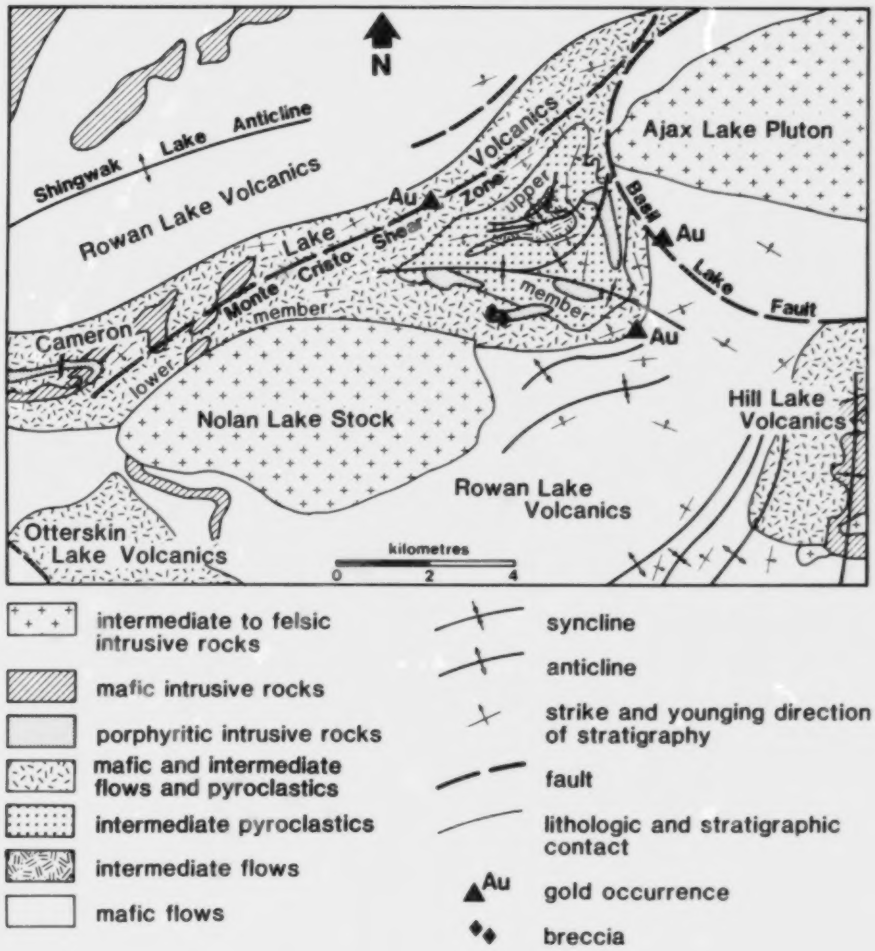

N
Shingwak Lake Anticline
Rowan Lake Volcanics
Cameron Lake Volcanics
Monte Cristo Shear Zone
upper member
lower member
Au
Ajax Lake Pluton
Basil Lake Fault
Nolan Lake Stock
Hill Lake Volcanics
Rowan Lake Volcanics
Otterskin Lake Volcanics
kilometres
0
2
4
intermediate to felsic intrusive rocks
mafic intrusive rocks
porphyritic intrusive rocks
mafic and intermediate flows and pyroclastics
intermediate pyroclastics
intermediate flows
mafic flows
syncline
anticline
strike and younging direction of stratigraphy
fault
lithologic and stratigraphic contact
Au gold occurrence
breccia

Figure 009.1. *Stratigraphy and structure of the Rowan Lake area.*

ally distinct geological regions are of note. The concave-east, curvilinear fault around the Ajax Lake Pluton (Basil Lake Fault, Figure 009.1) separates east-facing mafic flows on the east from the complex volcanic stratigraphy to the south and west. The metavolcanics between Cameron Lake and Rowan Lake have been subdivided by Blackburn and Hailstone (1983) into a lower mafic group (Rowan Lake volcanics) and an overlying diverse group (Cameron Lake volcanics). Figure 009.1 is a further refinement of this subdivision.

The Rowan Lake volcanics form the lower group consisting of mafic, massive, and pillowed flows with associated autoclastic breccia, pillow breccia, hyaloclastite, and plagioclase-phyric flows (leopard rock). This unit is folded around the Shingwak Lake Anticline, shown in the northwestern part of Figure 009.1, and is intruded by the Nolan Lake Stock in the south. Overlying the Rowan Lake volcanics are the Cameron Lake volcanics and the mixed assemblage on Hill Lake (Figure 009.1). The Cameron Lake volcanics can be subdivided into a lower diverse member consisting of interbedded mafic flows, intermediate to felsic pyroclastic rocks and minor metasediments, and an upper member of intermediate pyroclastic rocks with minor intermediate flows. The mixed assemblage on Hill Lake cannot be subdivided.

The base of the Cameron Lake volcanics is defined as the first appearance of intermediate to felsic pyroclastic units. The northern contact has a northeast strike north of Sullivan Bay on Rowan Lake. The southern contact, intruded in part by the Nolan Lake Stock, is not as clearly defined (Figure 009.1). The lower member of the Cameron Lake volcanics consists of massive and pillowed mafic flows, sheared and highly contorted mafic flows, intermediate to felsic pyroclastic rocks, and sheared pyroclastic and metasediments. Intermediate to felsic pyroclastic rocks consist of monolithic, coarse pyroclastic flows and quartz-feldspar tuffs. The quartz-feldspar tuffs are discontinuous along the northern shore of Sullivan Bay on Rowan Lake and exhibit variation in the quartz and feldspar ratios. These tuffs are interpreted to have been deposited by ash flow mechanisms.

The upper member of the Cameron Lake volcanics is a very distinct unit consisting of monolithic, intermediate pyroclastic rocks with minor interbedded intermediate flows (Figure 009.1). The member is predominantly pyroclastic in origin with the most common clast type being a quartz amygdular, feldspar phyric, intermediate volcanic rock. This type of clast is easily recognizable by its highly amygdular nature; amygdules range in size from less than 1 mm to greater than 1 cm. Textures of the amygdular clasts range from fine grained with a few amygdules, to scoriaceous. Clast shapes are very irregular (popcorn shaped) and vary in size from ash to bomb. The texture and shape of these fragments are evidence of their being essential clasts from a primary magma. Subordinate clasts of similar composition to the amygdaloidal fragments are feldspar phyric, massive, fine grained, and angular to subangular in shape and may be accessory clasts. The clasts are supported in a matrix of fine-grained, crystal-lithic tuff composed of the same material as the larger clasts. Deposits range from pyroclastic breccia to tuff. An excellent example of a coarse lithic-plagioclase crystal lapillistone is found along the southern margin of the upper member on the southern shore of Rowan Lake north-northwest of Newman Lake.

Bedding is generally very thick and massive and thinner beds may be graded, exhibiting gradational contacts. Interlayered with the pyroclastic deposits are pillowed, amygdaloidal and massive, feldspar-phyric intermediate flows. These flows are composed of material similar to the clasts within the pyroclastic units and to the dikes and sills intruding both the upper and lower members of the Cameron Lake volcanics.

Very fine grained, pumice-bearing felsic tuffs are associated with the upper member of the Cameron Lake volcanics and are found along the eastern margin of the unit near and along the Basil Lake Fault.

Based on the highly amygdaloidal nature of the clasts and flows, their massive thick bedded nature, and their gradational contacts, the upper member of the Cameron Lake volcanics is interpreted to have been deposited in a shallow water, proximal volcanic environment from a gas-rich magma of intermediate composition. Deposition of the pyroclastic rocks was by pyroclastic flow and fall-out mechanisms. The explosive eruptions sufficiently degassed the magma to allow minor eruptions producing the pillowed and massive flows before the onset of further explosive activity. Spatially limited chloritized zones within the upper member of the Cameron Lake volcanics are found on eastern Rowan Lake north of Wampum Lake. These irregularly shaped alteration zones are interpreted to be the result of synvolcanic alteration.

A mixed assemblage of flows and pyroclastic units outcrop between Hill Lake and the Lawrence Lake Batholith. They are not laterally extensive (Figure 009.1; Chivers, this volume, Figure 010.1). This assemblage consists of interbedded mafic and intermediate metavolcanics. The mafic metavolcanics comprise interbedded massive and pillowed flows, pillow breccia and hyaloclastite, variolitic flows, and feldspar-phyric, massive and pillowed flows and hyaloclastite. Interbedded with these are intermediate and intermediate to mafic tuff, lapilli-tuff, tuff-breccia, and a highly amygdaloidal mafic unit.

The mafic metavolcanics within this mixed assemblage contain similar lithologies as the Rowan Lake volcanics. Feldspar-phyric flows (leopard rock) are present in both the Rowan and Hill Lake volcanics and are absent from the Cameron Lake volcanics. The author has interpreted the Hill Lake volcanics to have been deposited during the waning phases of Rowan Lake volcanism and at the onset of the volcanism that deposited the Cameron Lake volcanics. This interpretation is based on the similarities between the mafic components of the Rowan Lake and Hill lake volcanics. The heterolithic nature and rounding of clasts comprising the interbedded pyroclastic rocks of the Hill Lake volcanics suggest that they may be the distal equivalent of the Cameron Lake volcanics. Isoclinal folding between the Cameron Lake volcanics and the Hill Lake volcanics obscures their interrelationships.

The extensive highly amygdaloidal mafic unit within the Hill Lake volcanics indicates a shallow water environment of deposition. This shallow water environment is suggested by the presence of pillow breccia and hyaloclastite into Fog Lake where autoclastic breccia and a peculiar unit of pillow breccia occurs (*see* Chivers, this volume). Chivers (this volume) notes the lack of lateral extent of the pyroclastic units on Hill Lake which indicates a small restricted basin for their deposition.

The Nolan Lake Stock (Figure 009.1) is a massive, potassium feldspar-phyric intrusion of monzonitic affinities. A narrow syenite body northeast of the Nolan Lake Stock contains syenite clasts in a mafic matrix as well as mafic material with a syenite matrix intimately mixed. It appears that this narrow body has been explosively emplaced into the mafic country rock. The Ajax Lake Pluton is a massive biotite granodiorite that appears to be part of the Lawrence Lake Batholith.

STRUCTURAL GEOLOGY

The structure of the Rowan Lake area is complex (Figure 009.1). Folding consists of an anticline centred on Shingwak Lake in the west that has a south-facing homoclinal limb and a complex of tight isoclinal folds in the east. The northern part of the Cameron Lake volcanics has been highly contorted during multiple phases of deformation. One zone of deformation exhibits a strongly foliated sequence that has been tightly folded. Granitoid intrusions crosscutting this strong foliation have themselves been folded.

The upper member of the Cameron Lake volcanics (Figure 009.1) has been folded into a trilobate synform. Between the southeastern limb of this fold and the Hill Lake volcanics many fold axes have been interpreted from top reversals. These folds obscure the relationship between the Cameron Lake volcanics and the Hill Lake volcanics.

The intense deformation in the northern part of the Cameron Lake volcanics may be due to increased or continuing folding and flattening of the eastern fold axes caused by the emplacement of the Ajax Lake Pluton. The trilobate fold structure appears to have formed through compression between the Nolan Lake Stock, the Ajax Lake Pluton, and the intrusive complex around Denmark Lake.

The Monte Cristo Shear Zone has demonstrated gold potential. This shear zone extends northeastward from Sullivan Bay through Rowan Lake north of the Ajax Lake Pluton (Figure 009.1). Further detail on this very complex shear zone is presented in this volume (*see* Melling, this volume). The Basil Lake Fault (Figure 009.1) and shear zone separates the mafic metavolcanics intruded by the Ajax Lake Pluton from the Rowan Lake, Cameron Lake, and Hill Lake volcanics. This fault is defined by shearing along the eastern shore of Rowan Lake, by a strong lineament and by lithological and structural changes across it (*see* Chivers, this volume).

ECONOMIC GEOLOGY

A number of gold occurrences including Nuinsco Resources Limited's Monte Cristo Deposit have been outlined by Beard and Garratt (1976). The three known occurrences in the eastern part of Rowan Lake are associated with shear zones. The Monte Cristo Deposit is along the major northeast-trending Monte Cristo Shear Zone. The Errington Prospect, southwest of the Ajax Lake Pluton, appears to be related to the Basil Lake Fault. The Wampum Lake Prospect east-northeast of the Nolan Lake Stock is in sheared mafic metavolcanics and is also near the transition of the underlying Rowan Lake volcanics and Cameron Lake volcanics (Figure 009.1). Blackburn and Hailstone (1983) noted a similar setting for Nuinsco Resources Limited's Cameron Lake Deposit. Melling (this volume) describes the relationship of the Monte Cristo Deposit to the Monte Cristo Shear Zone.

GUIDE TO PROSPECTORS

As Colvine *et al.* (1984) pointed out, Archean lode gold deposits appear to be related to deformation zones. With this model in mind, the Monte Cristo Shear Zone has potential for additional gold occurrences. The Basil Lake Fault is a major structure separating two geological environments and should be closely examined.

Chivers (this volume) notes the presence of carbonatized shear zones in the Brooks Bay (Rowan Lake) and Hill Lake areas. Thus, that part of the map area is of economic interest. A small granodiorite plug south of the eastern end of Hill Lake has many quartz veins and pyritiferous zones associated with it. The vicinity of this intrusion should be prospected.

The transition between the Rowan Lake volcanics and the Cameron Lake volcanics and the Hill Lake volcanics has potential for hosting gold deposits, especially if the structure is favourable.

The spatially-limited zones of chlorite alteration found within the upper member of the Cameron Lake volcanics, interpreted to be due to synvolcanic alteration, may be the result of submarine fumarolic activity and if ideal conditions prevailed at the time of gas discharge, then massive sulphide mineralization containing base metal may have been deposited. Thus, the upper member of the Cameron Lake volcanics have potential for hosting massive sulphide base-metal deposits.

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010. Geology of the Brooks Bay Area, District of Kenora

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INTRODUCTION

During the Summer of 1986, 120 km^2 in the Brooks Bay area was mapped by the author at a scale of 1:15 840 or 1 inch to 1/4 mile in conjunction with the Kakagi-Rowan Lake Synoptic Project (Johns, this volume). The map area is bounded to the north and south by Ajax and Holstein Lakes respectively, to the east by Emm Island of Lawrence Lake, and Brooks Bay on Rowan Lake to the west (*see* location map).

The map area is accessible by float-equipped aircraft and lakes within the area are connected by portages.

MINERAL EXPLORATION

In the past, gold has been the mineral of economic interest within the study area. A description of local gold occurrences was compiled by Beard and Garratt (1976) as part of a report on "Gold Deposits of the Kenora-Fort Frances Area".

Previously known gold mineralization occurs in the Errington Prospect, on the northeastern shore of Rowan Lake (Figure 010.1). In 1947, trenching and 39 diamond-drill holes totaling 3478 m (11 409 feet) delineated a 150 m long, 0.8 m wide zone with an average grade of 0.24 ounce gold per ton (Kenora Assessment Files, Resident Geologist's Office, Ministry of Northern Development and Mines, Kenora). Known current exploration activity has been restricted to exploration by Nuinsco Resources Limited on the Monte Cristo shear zone to the west of the map area. Some prospecting is being carried out in the area by a local lodge owner.

GENERAL GEOLOGY

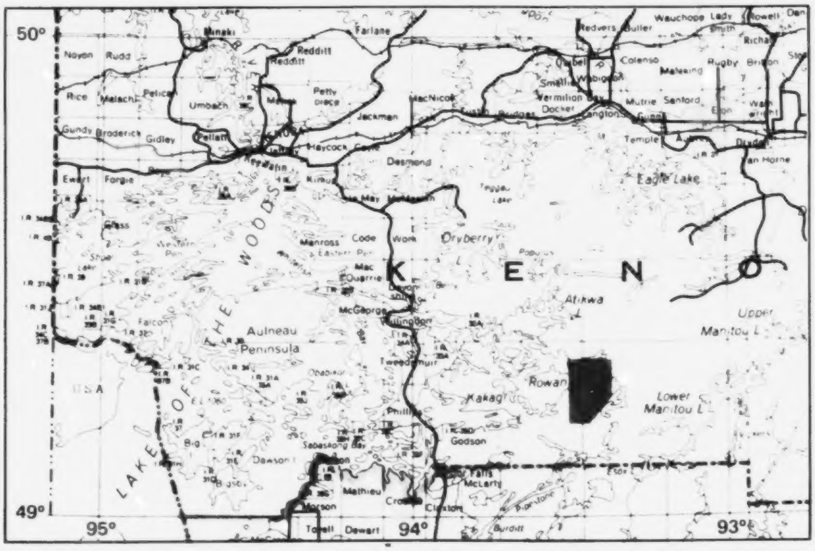
The map area, underlain by rocks of Archean age, is situated at the western end of the Wabigoon Subprovince. The supracrustal rocks are bounded to the north and east respectively by the Ajax Lake Pluton and the Lawrence Lake Batholith.

The area was previously mapped by Thompson as part of a regional study of the Rowan-Straw Lakes Area (Thompson 1936). Mapping in adjacent areas includes Rowan Lake to the west (Kaye 1973), Straw Lake to the south (Edwards 1983), and Schistose Lake to the southwest (Edwards 1980).

The area is underlain predominantly by interlayered massive, fine-grained mafic flows, pillowed flows, pillow breccia, hyaloclastite, autoclastic breccia, and intermediate pyroclastic rocks. These volcanic rocks have been divided into an upper sequence of interlayered mafic volcanics and intermediate pyroclastic rocks, and a lower sequence of predominantly mafic metavolcanics (*see* Johns, this volume; Figure 010.1).

The lower sequence of mafic metavolcanics is found at Brooks Bay of Rowan Lake, Fog Lake, and the western half of Hill Lake (*see* Figure 010.1). These massive and pillowed mafic flows are interlayered with units of hyaloclastite, autoclastic breccia, pillow breccia, feldspar-phyric mafic flows (leopard rock), and minor intermediate pyroclastic rocks.

Massive and pillowed mafic flows are fine grained and equigranular. Some flows contain anhedral to euhedral plagioclase phenocrysts up to 2 cm in size. Individual porphyritic flows are not traceable laterally. Within some flows at Brooks Bay,


50°
49°
95°
94°
93°
K E N O
LAKE OF THE WOODS
Minaki
Farlane
Reddit
Noyon
Rudd
Rice
Malachi
Pelican
Umbach
Petty
Jackman
MacNicol
Gundy
Broderick
Gidley
Pellatt
Haycock
Keewatin
Desmond
Ewart
Forgie
Redvers
Buller
Wauchope
Lady Smith
Rowell
Colenso
Melesing
Rugby
Britton
Smellie
Wabigoon
Vermilion Bay
Docker
Langton
Mutrie
Sanford
Temple
Van Horne
Eagle Lake
Teggau Lake
Glass
Manross
Code
Work
Dryberry L
Mac Quarrie
McGeorge
Tweedsmuir
Aulneau Peninsula
Atikwa L
Upper Manitou L
Lower Manitou L
Rowan
Kakagi
Falcon
U.S.A.
Big
Dawson
Sabaskong Bay
Godson
Mathieu
Morson
McLarty
Crozier
Claxton
Tovell
Dewart
Burditt

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

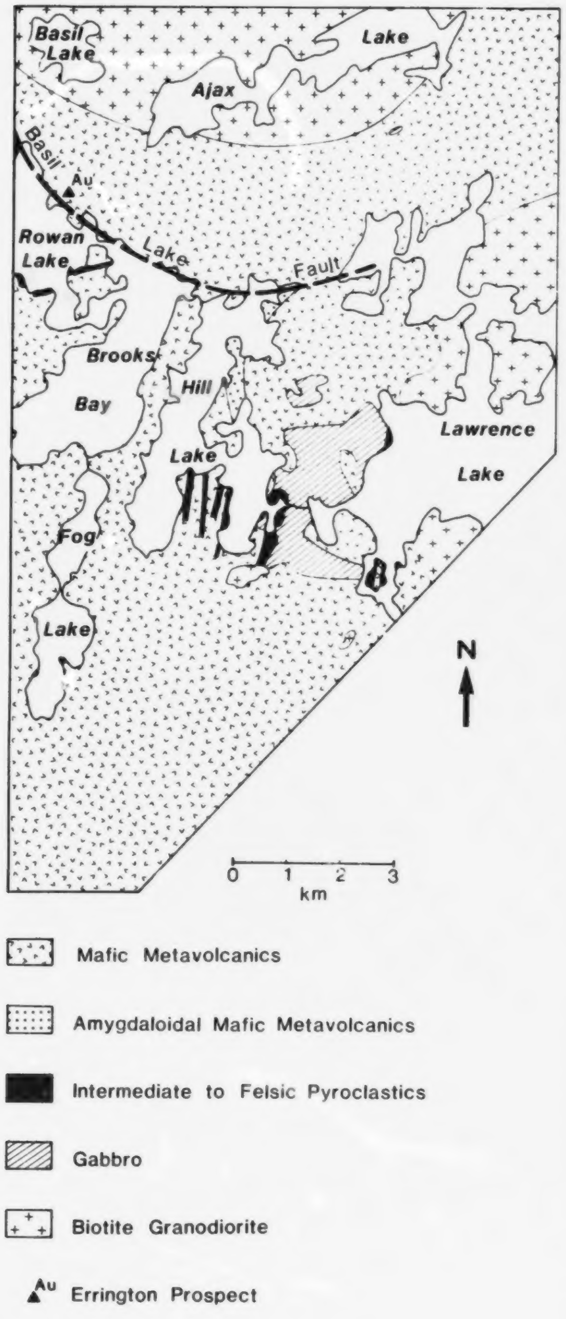


Figure 010.1. *Generalized geology of the Brooks Bay area.*

small pods of very fine grained euhedral crystalline calcite occur between the pillows.

In the lower sequence, mafic autoclastic breccia, hyaloclastite, and minor intermediate pyroclastic rocks are found in the southern half of the Fog Lake area. The autoclastic breccia is supported by a matrix of fine-grained crystalline calcite, small angular mafic fragments, and pods of euhedral pyrite. North of the autoclastic breccia, a unit of unusual broken pillow breccia (c.f. Carlisle 1963) was outlined. It contains subrounded to subangular mafic clasts having thin white micro-fractured chilled rims. These clasts are supported by a fine-grained hyaloclastite matrix, parts of which contain white spherulites. Interlayered with the pillow breccia are massive mafic spherulitic flows as well as a heterolithic intermediate lapilli-tuff.

Mafic flows on the northern shore of Brooks Bay, north of the curvilinear, concave-east Basil Lake Fault, are not part of the lower sequence but are part of a different stratigraphic package. This package is defined by the presence of massive and pillowed mafic flows and the absence of intermediate pyroclastic rocks. These flows are highly saussuritized and have a buff weathered surface and a light apple green fresh surface. Small amounts of plagioclase phenocrysts are scattered throughout some of the pillowed and massive flow units.

The upper sequence consists of two units: a) the Cameron Lake volcanics, found in the eastern side of Rowan Lake (*see* Johns, this volume; Figure 010.1); and b) the Hill Lake volcanics, found in the eastern Hill Lake area (*see* Johns, this volume; Figure 010.1).

The Cameron Lake volcanics are a diverse assemblage of mafic to intermediate flows, and intermediate to felsic pyroclastic rocks. There are no interlayered plagioclase phyric flows within the mafic metavolcanics of the upper sequence, and this distinguishes them from the mafic metavolcanics of the lower sequence. Mafic flows are fine grained, equigranular, and massive or pillowed in nature. The mafic metavolcanics are interlayered with intermediate and felsic pyroclastic rocks.

Fine felsic tuffs, some units containing collapsed pumice, are found only in the northwestern corner of the map area. Intermediate crystal tuffs and lithic-crystal lapilli-tuffs are interbedded with massive and pillowed mafic flows. Fine-grained, spherulitic, intermediate tuffs are commonly found as tops to the lapilli-tuff beds. All units of the Cameron Lake volcanics are cross-cut by fine-grained equigranular and feldspar porphyritic intermediate dikes.

The Hill Lake volcanics consist of a highly folded sequence of interlayered mafic and intermediate metavolcanics and the stratigraphy is difficult to interpret (Figure 010.1). Mafic metavolcanics in this area are interbedded with intermediate tuff, lapilli-tuff, and pyroclastic breccia as well as mafic hyaloclastite, pillow breccia, plagioclase phyric flows (leopard rock), amygdaloidal, and variolitic flows.

Mafic and intermediate pyroclastic rocks outcrop only at the southern end of Hill Lake and do not have much lateral extent, suggesting deposition in a restricted basin. Two types of intermediate pyroclastic units are found: the more extensive is a monolithic matrix-supported pyroclastic breccia; the matrix being crystal tuff. The other type is heterolithic pyroclastic breccia. This unit is clast-supported, and has a very fine grained, dark green mafic matrix. Fine-grained clasts, vesicular clasts, and feldspar-phyric clasts range from intermediate to mafic in composition. Mafic and intermediate tuffs are interbedded with both of these pyroclastic types as well as the mafic flows.

A laterally extensive unit of amygdaloidal mafic flows marks the western boundary between the mafic volcanic rocks of the upper and lower sequence at Hill Lake. This unit is characterized by large, oval, quartz-filled amygdules and gas cavities up to 10 cm in size. Most of the unit occurs as pillow breccia, although minor pillowed and massive flows were noted. These characteristics suggest that this unit resulted from the deposition of a volatile-rich magma in a shallow water environment.

"Leopard rock", within the map area, is defined by the author as a mafic rock with greater than 20 percent saussuritized plagioclase phenocrysts greater than 1 cm in size. This rock type is found throughout the map area in the lower sequence and only in the Hill Lake volcanics of the upper sequence. It parallels stratigraphy, although it does not form traceable stratigraphic units, and is both extrusive and intrusive. Both plagioclase phyric flows and hyaloclastite containing large (1 to 4 cm) plagioclase phenocrysts were observed on the eastern side of Hill Lake. Small, zoned, intrusive sills, grading from exclusively hornblende-phyric gabbro at the base upwards into entirely plagioclase-phyric anorthositic gabbro, were found, particularly on the eastern shore of Brooks Bay.

A large north-trending synvolcanic unit of feldspar- and hornblende-phyric gabbro intrudes the metavolcanics east of Hill Lake.

Metavolcanics within the map area have been carbonitized and epidotized. Carbonitization was noted in the mafic flows in the central part of the Brooks Bay area and in the western part of the Hill Lake area. Many small intensely altered shear zones were also noted in both areas. Quartz-tourmaline veining is commonly found within the mafic flows at Brooks Bay.

Epidotization is mainly restricted to the mafic metavolcanics north of the Basil Lake Fault, and south of Fog Lake, eastward towards Hook Lake.

The metavolcanics of this region have been metamorphosed to greenschist grade. However, the intrusion of the Ajax Lake Pluton and the Lawrence Lake Batholith have increased the metamorphic grade of the adjacent metavolcanics to amphibolite. The metamorphic aureoles of the Ajax Lake Pluton and the Lawrence Lake Batholith are approximately 1000 and 750 m wide respectively.

Two intermediate to felsic intrusive units, and several smaller plugs, intrude the supracrustal rocks. The Ajax Lake Pluton is a massive, inequigranular to porphyritic biotite granodiorite. A sharp contact between the pluton and the metavolcanics is evident, although minor dikes in the supracrustals near the contact were observed.

The Lawrence Lake Batholith is a multiphase intrusion (Edwards 1983). The youngest and most extensive phase of the batholith within the map area is biotite granodiorite, with minor muscovite and hornblende. Unlike the Ajax Lake Pluton, the batholith has a wide contact zone characterized by xenoliths of mafic and intermediate metavolcanics. An older foliated biotite hornblende tonalitic marginal phase has been intruded by the quartz-rich granodiorite.

One zone of the tonalite is coarse grained, inequigranular, and contains approximately 50 percent irregular-shaped blebs of polycrystalline quartz, in a biotite-rich matrix. In some outcrops this unit appears to be pyroclastic with feldspar and hornblende porphroblasts occurring in both the clasts and matrix. This problematic unit may represent assimilation of intermediate pyroclastic rocks.

A few small, massive plugs intrude the supracrustal rocks. They are predominantly biotite granodiorite although quartz veining and pyrite-rich zones are associated with one small intrusion south of the eastern end of Hill Lake.

STRUCTURAL GEOLOGY

There do not appear to be any major faults within the map area, with the exception of the Basil Lake Fault (Figure 010.1) which is a strong, concave-east fault; intense shearing is found along the eastern shore of Rowan Lake. Structural as well as lithological changes occur across this structure.

To the northeast of the Basil Lake Fault, foliation within the highly saussuritized mafic metavolcanics trends southeast. The mafic and intermediate metavolcanics to the south of the fault have foliations which vary from northeast to east. The foliation in both areas dips steeply from 70° southeast to 90° (Figure 010.2). Bedding immediately to the north and south of the fault strikes northwesterly.

Steeply dipping foliation in the central part of the Brooks Bay area strikes northeasterly and veers to the north around Hill Lake. In the vicinity of Fog Lake, foliation is variable, but predominantly northerly. Bedding at both Brooks Bay and Fog Lake strikes northeastward to east-southeastward, while on the eastern side of Hill Lake it strikes northwestward (Figure 010.2).

Top determinations were made on the basis of the packing of pillowed flows, normal grading of clasts within the pyroclastics rocks, and mineralogical zoning in the porphyritic metavolcanics. Numerous folds have been interpreted on the basis of top reversals across the map area. The metavolcanics on the eastern side of Hill Lake appear to be more tightly folded than those at Brooks Bay and Fog Lake (Figure 010.2). All of the folds are subparallel with axial traces which strike roughly northeastward.

ECONOMIC GEOLOGY

Exploration activity within the map area has focused on gold.

The Errington Prospect (Beard and Garratt 1976), a small gold showing on the eastern side of Rowan Lake (Figure 010.1), is spatially related to the Basil

Lake Fault. Gold occurs within the metabasalt and dacitic breccia zones, and is associated with pyrite, chalcopyrite, pyrrhotite, and sphalerite (Neilson and Bray 1981). Gold is also found in a few quartz veins, some up to 1 m wide, that occupy the dacite-metabasalt contact or occur as tension fractures in felsic dikes (Beard and Garratt 1976). The estimated tonnage and grade for this occurrence is 224 000 tons at approximately 0.24 ounce gold per ton (Neilson and Bray 1981).

Mineralization on the Wampum Lake Prospect (Clark 1983), which is just to the west of the map area, is also located within a shear zone in the mafic volcanic rocks. This shear zone contains two parallel zones of mineralization 30 m apart (Beard and Garratt 1976). Estimated tonnage and grade for this occurrence is 15 000 tons at approximately 0.08 ounce gold per ton (Neilson and Bray 1981).

Numerous small, carbonitized, pyrite-bearing, east-trending shear zones occur at Brooks Bay and Hill Lake. During the course of mapping,numerous grab samples were collected for gold assay; however, no results were available at the time of writing. These shear zones, as well as the many noncarbonitized but sulphide-rich zones, should be examined to determine their gold potential.

The Errington Prospect is spatially related to the Basil Lake Fault, and Colvine *et al.* (1984) have shown that Archean lode gold deposits are spatially related to major shear zones. Therefore, the units along this lineament should be examined further.

The shear zone in which the mineralization on the Wampum Lake Prospect is found strikes roughly east-west, and may in fact extend into the map area. Further prospecting for gold along its length is warranted.

Quartz veining associated with shear zones may also contain gold mineralization. Several quartz±tourmaline±carbonate±pyrite veins occur in the central part of Brooks Bay and should be more closely examined.

A small biotite granodiorite plug south of the eastern end of Hill Lake contains many quartz veins and pyrite-rich zones. A high degree of alteration, due to the introduction of the quartz veins and pyrite within the plug, is evident. This signifies a large amount of fluid movement in and around the plug, and as such, both the plug and the host rock appear to be favourable areas for gold mineralization.

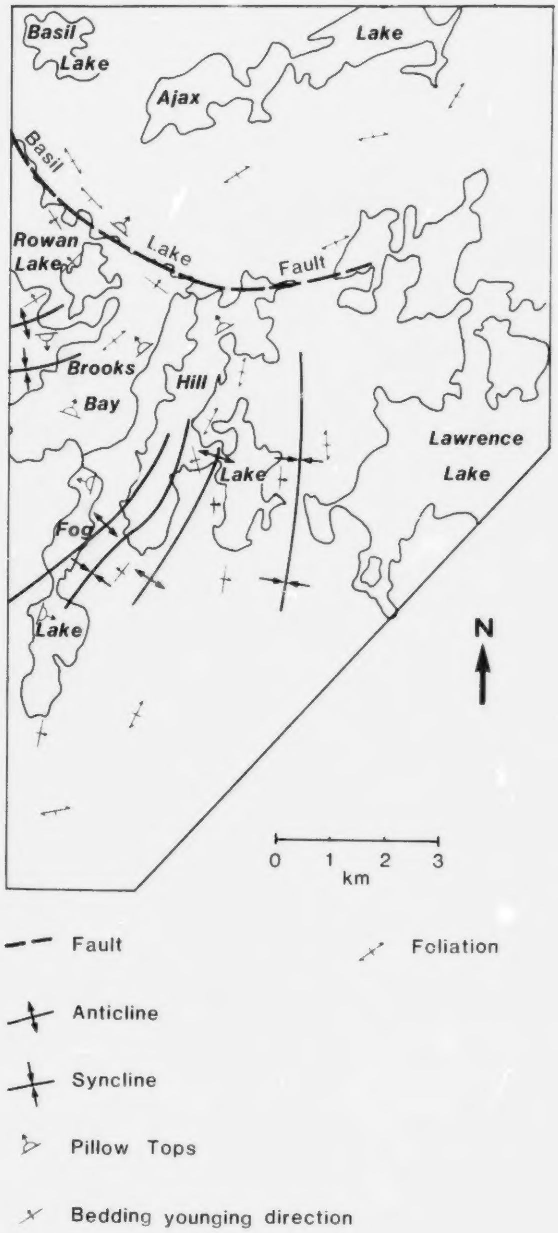


Figure 010.2. *Structural geology of the Brooks Bay area.*

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011. Ultramafic to Felsic Dikes in the Atikwa Plutonic Complex of the Atikwa–Lawrence Volcanic–Plutonic Terrain, District of Kenora

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INTRODUCTION

The Atikwa plutonic complex (APC) (location map) is part of the 3000 km² Atikwa-Lawrence volcanic-plutonic terrain (Edwards and Davis 1984). This terrain has central plutonic complexes that range in composition from mafic to felsic; metavolcanics surrounding the plutonic complexes have a range of composition similar to that of the intrusions, comprising basalt at the base, overlain by andesite, and less commonly rhyolite. Zircon U-Pb geochronology provides evidence for the contemporaneous evolution of much of the volcanic and plutonic suite between approximately 2745 Ma and 2720 Ma B.P. (Davis and Edwards 1985).

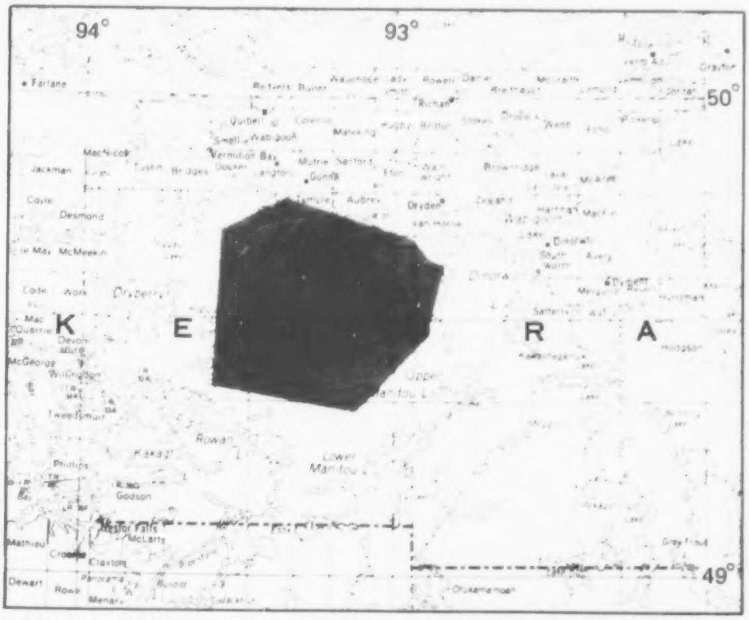
Preliminary large-scale work by Edwards and Davis (1984) and Davis and Edwards (1985) on the APC and the Lawrence plutonic complex of the terrain provides the base for the present field study examining the ultramafic to felsic dikes (Group 4 described below) in the APC. These dikes have common physical and chemical characteristics which suggest they may be part of a consanguineous suite. The broad aim is to understand the physical, chemical, and temporal evolution of the volcanic-plutonic terrain in the context of the geology of the Wabigoon Subprovince.

DESCRIPTION OF ROCK TYPES IN THE PLUTONIC COMPLEXES

From our previous field and chemical investigations, rocks in the plutonic complexes of the terrain can be divided into six distinct groups as follows:

Group 1: Mafic to ultramafic intrusive rocks are found discontinuously at the margin of the plutonic complexes. The Mulcahy Lake intrusion, as an example, is predominantly gabbro and layered gabbro (Sutcliffe and Smith 1985). The zircon U-Pb age for the Mulcahy intrusion is given as 2733.2 (+1.0/-0.9) Ma by Morrison *et al.* (1985). At Denmark and Atikwa Lakes, this group is represented by unlayered gabbro and less commonly by peridotite (Davies 1973). The metabasalts hosting these intrusions exhibit variable contact effects; pyroxene hornfels with locally abundant orthopyroxene and associated partial melt textures are not common. At Mulcahy and Denmark-Atikwa Lakes, the intrusion seems to have been into already-folded rocks suggesting that the host metabasalts may be quite old.

Group 2: (Pyroxene)-biotite-amphibole diorite and quartz diorite to amphibole-biotite tonalite accompanies and partially surrounds the mafic to ultramafic rocks of group 1. With increasing SiO_2 there is a general decrease in Al_2O_3, CaO, Co, and Sc. The rare



LOCATION MAP Scale : 1:1 584 000 or 1 inch to 25 miles.

earths elements (REE) exhibit fractionated chondrite-normalized patterns with La/Yb increasing with SiO_2 enrichment. Small positive Eu anomalies are rare. Three rocks of this group have been dated with high precision zircon U-Pb isotope geochronology. Quartz diorite near the southern end of the Lawrence plutonic complex yields an age of 2732.4 (+2.1/-1.8) Ma. Two tonalite samples near the northern end of the APC give 2732.2 (+2.9/2.9) Ma and 2731.8 (+1.6/-0.9) Ma (Davis *et al.* 1982). Each of these rocks is approximately contemporaneous with the 2733.2 (+1.0/-0.9) Ma age for gabbro in the Mulcahy Lake layered mafic intrusion (Morrison *et al.* 1985). A direct petrogenetic relationship, if it exists, between rocks of group 2 and group 1 is not yet clear, although field evidence suggests that they were emplaced contemporaneously. The most likely origin, based on field relations and geochemistry (Davis and Edwards 1985), is the mixing of mafic magma of the layered intrusion with partial melts of its basalt host. Group 2 diorite-quartz diorite is probably not primary andesite melt because of its low Ni content.

Group 3: Amphibole-biotite tonalite and trondhjemite to granodiorite also accompanies rocks of group 1 and group 2. Zircon U-Pb isotope geochronology (Davis and Edwards 1985) confirms that they were emplaced at approximately the same time as group 1 and group 2. Group 3 is chemically characterized by a low La/Yb compared to group 2, generally negative Eu anomalies, although positive anomalies may occur at the contact with the host metavolcanics, and a differentiated major element signature with SiO_2 ranging from 72 to 76% and Al_2O_3 from 12.3 to 14.5%. Gold has been found in pyritized, sericitized, and locally hematitized zones, and in quartz veins adjacent to faults in rocks of this group. Some samples carrying gold values are also slightly enriched in heavy REE, suggesting there may be a link between igneous processes and gold deposition here, or that post-igneous gold-bearing fluids may have been enriched in HREE. The localization of gold in and near fault zones supports its epigenetic origin. Group 3 rocks may have originated by the partial melting of basalt, leaving a pyroxene-rich residue, or by differentiation in the group 2 system.

Group 4: (Amphibole)-biotite tonalite to trondhjemite and granodiorite occupy the central parts of the plutonic complexes and from field relations post-date groups 1, 2, and 3. The age determinations done so far indicate these rocks may have been emplaced as much as 14 Ma later than the rocks of groups 1, 2, and 3. SiO_2 ranges from 67 to 75% with concomitant ranges of Al_2O_3 from 14 to 16.6%, which is generally higher than group 3 rocks of similar silica content. They also have more Sr and Ba but less Th, Hf, Sc, Zr, and greater La/Yb than group 3 rocks of similar silica content. A slight positive Eu anomaly that increases with decreasing total REE, is evident in many of these rocks. The fractionated REE pattern and low Sc abundances compared to group 2 rocks, are consistent with the origin of these rocks by low temperature melting of predominantly the plagioclase component of a basaltic parent, leaving a mafic residue rich in amphibole and pyroxene. The positive Eu anomalies probably result from feldspar accumulation over a zone of melting in which the bulk of the melt is feldspathic with a minor amount of entrained mafic minerals.

Group 5: Ultramafic to felsic dikes intrude many phases of the APC. They vary in width from a few centimetres to tens of metres. The ultramafic dikes are usually amphibolitic, biotitic, clinopyroxenite or amphibolite with abundant opaque oxides and locally, relict orthopyroxene and olivine. These dikes grade into biotite-amphibole gabbro. The intermediate composition dikes are commonly amphibole, plagioclase, and biotite phyric. The felsic dikes are similar to the intermediate dikes, but have more quartz and may exclude amphibole. Preliminary petrochemical data indicates that some of the mafic dikes are high in Cr but also enriched in the incompatible elements Ba, Rb, and in Sr, whereas the intermediate and felsic dikes are enriched only in the latter. In the field, there is considerable evidence for melting of the host granitoid, and concomitant magma mixing adjacent to ultramafic to mafic dikes. In some outcrops, pillows of mafic magma are contained within a fluidal-textured matrix of hybrid diorite to granodiorite. Ultramafic dikes grade along strike into a breccia of host granitoid with a matrix of material resembling the intermediate or felsic dikes. Near some ultramafic dikes are local pods and veins of microcline-phyric granodiorite to quartz monzonite, in which the phenocrysts are sometimes rimmed with albite.

Group 6: Small post-tectonic plutons are scattered throughout the volcanic-plutonic terrain. They are usually amphibole-biotite granodiorite to quartz monzonite which, rarely, have muscovite as a second mica. Sphene is more abundant than in any of the other groups, accounting for up to 4%. Many of these plutons have large microcline phenocrysts, sometimes with albitic rims. Locally, trains of mafic inclusions may be remnants of mafic dikes, possibly of group 5, which were a causative agent in generating these plutons at depth.

DETAILED DESCRIPTION OF GROUP 5 ROCKS

Ultramafic to felsic dikes intrude foliated, medium-grained tonalite and granodiorite in the APC near Tadpole and Weiseleno Lakes. Their absolute age has not yet been determined, but, based on field relations, they are younger than 2720 Ma and may be as young as 2700 Ma. They may be analagous to rocks of similar composition in the Lac des Iles area (Sutcliffe and Sweeny 1986), though smaller in scale.

The following features are seen in most of the mafic to felsic samples examined:

1. Metamict allanite is common and is usually surrounded by epidote.
2. Epidote is ubiquitous and is normally partially symplectitic with plagioclase.
3. There is more corrosion of amphibole by biotite as the color index decreases in the dikes, amphibole is generally absent in the more felsic dikes.

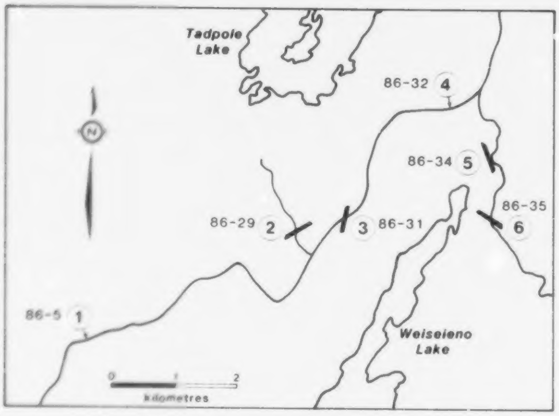


Figure 011.1. *Site locations of ultramafic to felsic dikes and related rocks along bush roads in the Atikwa Plutonic Complex.*

4. Sphene forms from the breakdown of oxides. Some samples have strongly zoned sphenes which, rarely, have hematite cores. Calcium for sphene seems to come, at least in part, from the reaction of amphibole to biotite.

At Site 1 (Figure 11.1), rounded and pillowy to subangular compound mafic dike fragments, usually less than a metre across, are included in an irregular hybrid dike that varies compositionally from intermediate to felsic. The mafic inclusions have amygdule-like structures filled with quartz and feldspar which may be inclusions of melted granodiorite host; some mafic fragments also have leucocratic back-veins. Less discrete mafic inclusions have a swirly structure and grade into the composition of the dike matrix. The dike also has nebulous inclusions of the host granodiorite.

Site 2 (Figure 11.1) is a composite mafic dike that is at least 20 m wide and which has been traced for approximately 150 m along strike. The margins of the dike are amphibole-biotite gabbro, while the core is porphyritic, with amphibole exhibiting seriate porphyritic textures. In the amphibole-biotite gabbro, prismatic amphibole has grown to 3 cm length. Some of these crystals are skeletal, suggesting growth under quenching conditions. By contrast, there are equant amphibole phenocrysts up to 1.5 cm across in the seriate phase, but the phenocrysts contain numerous smaller clinopyroxene crystals. The matrix between the amphibole is composed of small euhedral clinopyroxene crystals, some enclosing amphibole, set in large poikilitic plagioclase. Both subphases have 5 to 10% quartz.

The southeast contact of this dike is partly exposed. Here, there is abundant evidence for mixing of melted granodiorite host with the mafic dike material. There are inclusions of mafic material in felsic, and vice versa. Dike-like masses of granodiorite intrude and mingle with the gabbro along the contact. A granodiorite sample taken half a metre from the contact has a myrmekite-like texture that is localized in a semicontinuous, vein-like fashion along the edges of some plagioclase grains. This texture has not been observed in the granodiorite elsewhere, and may be a contact metamorphic or incipient melting effect.

Site 3 (Figure 11.1) is a mafic to ultramafic mass at least 15 m across whose contacts are not exposed. The central part of this mass is peridotite. The texture here is poikilitic, consisting of dusty olivine enclosed by large, pale green to brown amphibole or smaller pink orthopyroxene poikilocrysts. Clinopyroxene is also enclosed by the amphibole but is corroded. Locally, there is a complex zonal intergrowth of amphibole and clinpyroxene similar to that seen in the porphyritic subphase at Site 2. Phlogopite also, less commonly, forms poikilocrysts in this subphase. The peridotite grades into amphibole gabbro.

On the north side of the road is an apophysis of pink plagioclase in the gabbro. It consists of medium-grained plagioclase crystals in a granular matrix of finer grained plagioclase and possibly some K-feldspar. Miarolitic cavities are common and contain calcite, zoned epidote, gypsum, or a green to yellow, radiating, chlorite-like mineral, probably stilpnomelane. Calcite occurs mainly as fillings of the central parts of some of the larger plagioclase crystals. This rock may be a differentiate of mafic to ultramafic magma, but it may also be a melt of the host granodiorite.

Outcrops in the vicinity of this location are intruded by breccia dikes, less than 2 m wide, that have variable amounts of subangular to rounded fragments of mafic to felsic composition and isolated amphibole xeneocrysts. The groundmass of these dikes resembles the groundmass in the dike at Sites 1, 4, and 6, and that of late intermediate dikes elsewhere in the plutonic complex.

Site 4 (Figure 11.1) has a discontinuous, 5 m wide dike and associated agmatite. The main part of the dike is gabbro, but in the agmatite, dike composition is intermediate to felsic and similar in appearance to dikes elsewhere in the plutonic complex. Pink quartzo-feldspathic pegmatite is intimately associated with the gabbro. A broken dike of pegmatite cuts part of the gabbro, but it also forms flame-like structures protruding into the gabbro. The pegmatite here is probably melt of the host granodiorite.

Site 5 (Figure 11.1) is a 15 to 20 m wide dike of biotite-amphibole gabbro. This rock is peculiar, consisting of poorly to well defined, irregular, interconnecting leucocratic patches, 2 mm to several centimetres long, set in a melanocratic matrix. On the weathered surface the texture somewhat resembles snowflakes. The leucocratic patches are predominantly large, compound plagioclase poikilocrysts with sparse biotite and amphibole inclusions. Equal proportions of amphibole and biotite with minor epidote, sphene, allanite, opaque oxides, and garnet comprise the melanocratic portion. The garnet here may be grossular having formed from the metamorphism of epidote in the host rock. This rock also has 5 to 10% quartz.

Where the contact with the host granodiorite is exposed, the leucocratic patches are smaller and merge with the host. These patches could be interpreted as ocelli if they resulted from primary immiscibility in an evolving magma, but it is more likely that they are caused by limited miscibility between a mafic magma and the melt of its host granitoid.

Site 6 (Figure 11.1) is geologically similar to Site 1 but is larger and more diverse. The external contacts of the compound dike are not exposed, however there are numerous internal contacts between hybrid subphases. Here, pillowy masses of mafic rock, locally with "snowflake"-like texture, are suspended in a matrix with a similar variation in composition, which is in some areas gradational, but in other areas is associated with schlieren. The hybrid matrix locally has numerous rapakivi feldspars and, less commonly, oval quartz masses resembling amygdules. The latter are interpreted to be quartz fillings of vapour bubbles possibly resulting from boiling of the melted host granitoid.

SUMMARY

From field evidence, ultramafic to felsic dikes in the APC seem to form a consanguineous suite exhibiting several common features. Ultramafic to mafic parts of the suite form dikes or complex, composite, irregular masses associated with which are hybrid intermediate to felsic matrix, dikes and breccia dikes of mixed compositions. Intermediate to felsic dikes elsewhere in the APC are discrete bodies and are similar in texture and composition to the hybrid matrix in the complex dikes. Locally, at least, aplite-pegmatite may have been generated adjacent to some of the mafic-ultramafic bodies.

The ultramafic to felsic dike suite probably has a common origin where basalt or perhaps komatiitic magma was injected into the lower part of the APC. The immediately adjacent granitoid rocks were fluxed and partly mixed with the more mafic magma and injected higher into the crust as dikes. These dikes in the APC were probably a late, small-scale manifestation of the broader process of basalt (or komatiite) injection that was the driving force in the long-term evolution of the volcanic-plutonic terrain. They survived by virtue of the fact that there was not more profuse mafic or ultramafic magma and heat to drive the evolution of the APC to the stage of gneissic diapirism (as for example in much of the Wabigoon Diapiric Axis; Edwards 1985).

The late, incompatible-element-rich plutons in volcanic-plutonic terrain, and the late quartz monzodiorite to granite plutons in the Wabigoon Diapiric Axis may have been produced by the emplacement of similar but larger scale dike suites and their attendant melting and mixing processes, low in the crust. Volcanic eruption may have accompanied these intrusions, in which case, the volcanic products would have been mafic to felsic and probably alkalic, possibly resembling sanukitoid magmas proposed by Shirey and Hanson (1984), or trachybasalt high in the sequence in the Sunshine Lake area (Blackburn 1981).

Future field work on these dikes will be aimed at documenting their distribution, size, and shape, and will include water-pump stripping of pertinent outcrops. Electron microprobe mineral analysis, and major, trace, and isotopic analysis, hopefully, will support the field evidence for consanguineity of the dike suite in the APC, and for its origin by partial melting of the host rocks and subsequent hybridization of the mafic magma.

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012. Melgund Lake Area, District of Kenora

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

The Melgund Lake area is bounded by 49°37′25″N and 49°53′46″N Latitudes and by 92°16′38″W and 92°24′44″W Longitudes (*see* Location Map). All of Avery, MacFie, and McAree Townships (approximately 173 km^2) were mapped at a scale of 1:15 840 during the 1986 field season. Access to the map area is easily obtained from the Towns of Dryden (43 km to the west) and Sioux Lookout (55 km to the north).

MINERAL EXPLORATION

Gold exploration from the early 1900s to World War II resulted in the discovery of the Midas Occurrence in the eastern part of McAree Township (Hurst 1933) and the Alto-Gardner Occurrence in MacFie Township (Satterly 1943) (Figure 012.1, this report). Both areas are characterized by gold and chalcopyrite in quartz veins hosted by intensely sheared and carbonate altered mafic metavolcanics.

Discovery of gold mineralization in Echo Township sparked intensive exploration activity between 1946 and 1952 and resulted in outlining the Goldlund Deposit 1000 m north of the map area (Page and Christie 1980). Continuing interest in gold has resulted in ongoing exploration in McAree Township by a number of companies of which Camreco Incorporated and Tarbush Lode Mining Limited are most active.

Other gold occurrences in the map area include the Johnson Occurrence on Sandy Beach Lake, a gold occurrence in Avery Township currently being explored by Noranda Exploration Company Limited (Glatz Option) and gold in quartz veins and silicified feldspar porphyry similar to the Midas and Alto-Gardner Occurrences in eastern McAree Township (Rivers Option; Figure 012.1, this report).

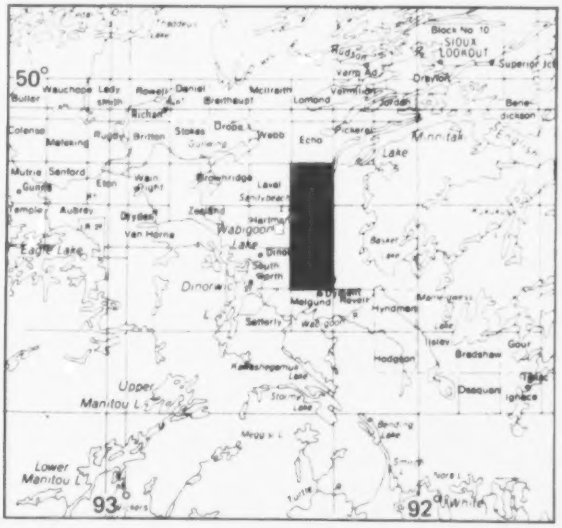
Exploration for base metals began in the 1960s (Page and Christie 1980) and has been sporadic since that time. A number of mining companies have explored for copper, zinc, and nickel, but no significant discoveries have been reported.

Currently there are a number of mining claims in good standing throughout the map area. The majority of the claims cover ground in northwestern McAree Township in the vicinity of the Goldlund Deposit. During the field season only Noranda Exploration Company Limited was active on their claims (Glatz Option) in Avery Township, carrying out geochemical and geological surveys (Paul Neilson, Noranda Exploration Company Limited, personal communication, 1986).

GENERAL GEOLOGY

The map area is underlain by a Precambrian assemblage of mafic, intermediate, and felsic metavolcanics, metasediments, and mafic and felsic intrusive rocks.

Avery Township and the southern half of MacFie Township are underlain by predominantly mafic flows and derived flow breccias. Flow morphology includes fine- to coarse-grained gabbroic massive flows, pil-


Block No 10
SIOUX LOOKOUT
Superior Jct
50°
Wauchope
Lady smith
Rowell
Daniel
Mcllraith
Breithaupt
Lomond
Vermilion
Jordan
Bene-dickson
Buller
Richan
Colenso
Melesing
Rugby
Britton
Stokes
Drope L
Webb
Echo
Pickerel
Minnitaki Lake
Mutrie
Sanford
Gunne
Eton
Wain wright
Brownridge
Laval
Sandybeach
Temple
Aubrey
Dryden
Zealand
Hartman
Van Horne
Wabigoon Lake
Eagle Lake
Dinorwic
South Porth
Melgund
Revell
Hyndman
Satterly
Wabigoon
Hodgson
Bradshaw
Gour
Upper Manitou L
Kawashegamuk Lake
Stormy Lake
Dasquan
Ignace
Bending Lake
Lower Manitou L
93°
92°

LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

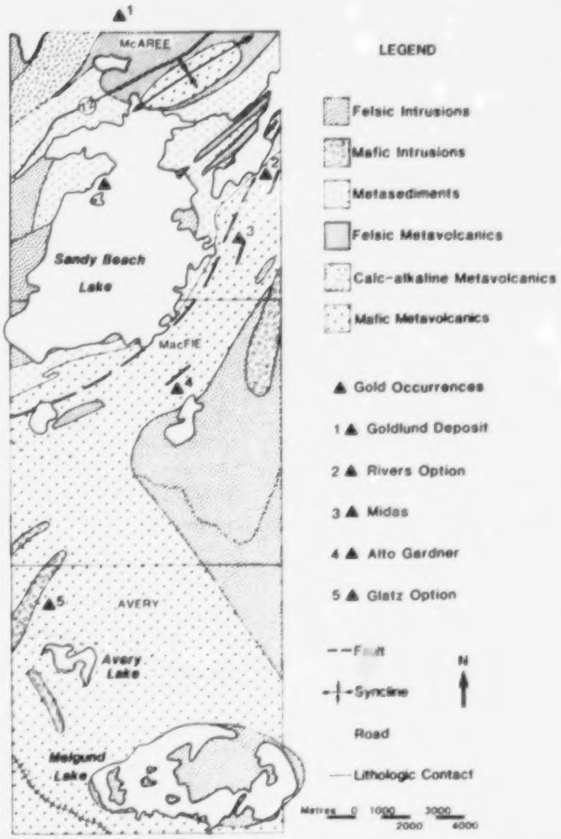


Figure 012.1. *General geology of the Melgund Lake Area.*

lowed flows, and lava tubes, defined as pillow-like structures greater than 2 m in long axis dimension. Pillow breccias, isolated pillow breccias, and not commonly, hyaloclastites overlie the flows. There is very little interflow metasediment, and pyroclastic rocks are unknown in this sequence.

In the Avery Lake area, pillow shapes are irregular to amoeboid and there is a great amount of interselvage material. Flows are highly amygdaloidal to vesicular and pillow breccia is more common than in other areas. These features are interpreted to represent a shoaling sequence in which the volcanic pile approached the water's surface. In this sequence stratigraphic facings from the amoeboid pillow shapes are unreliable and cannot be used to determine fold structures or stratigraphic facing. Instead, the vertical transition from massive flows to pillowed flows to flow breccia provides more reliable top indication in the Avery Lake area.

Plagioclase-phyric flows ("leopard rock") are a major feature of the mafic metavolcanics in Avery and MacFie Townships. A complete gradation is observed from aphyric flows and flow breccias to porphyritic flows exhibiting densely packed large (6 cm) euhedral plagioclase phenocrysts and flow breccias. Separation of plagioclase-phyric sequences from aphyric sequences was not possible at the scale of mapping because of the gradation between the two sequences and their intimate intercalation.

In McAree Township mafic metavolcanics are exposed in the core of a structural dome southeast of Highway 72 (Figure 012.1). These rocks are predominantly heterolithic epiclastic and pyroclastic tuff-breccias and lapilli-tuffs with minor massive flows and hornblende-rich wackes. Felsic clasts in these rocks are similar to the surrounding felsic metavolcanics which suggest the mafic sequence is younger than the felsic sequence.

In the northwestern part of McAree Township a mafic to intermediate metavolcanic sequence is exposed and represents the extension of the geology at the Goldlund Mine into the map area. These metavolcanics are unlike the other mafic sequences in that they are hornblende-phyric. Prominent millimetre-sized hornblende porphyroblasts and stretched primary hornblende phenocrysts occur throughout the rocks and indicate that these rocks are likely of calc-alkalic affinity. The rocks are composed predominantly of andesitic to dacitic pyroclasts in a mafic tuff matrix. Massive, scoriaceous and pillowed flows are minor components in the northern part of the sequence. A variolitic dacite flow is part of this sequence and appears to correlate with similar flows on the Goldlund Property. These rocks are highly deformed and sheared. This has obscured stratigraphic relationships; however, these rocks appear to underlie the felsic metavolcanics in north-central McAree Township. A pervasive magnetite alteration is strongly developed in the northern part of the sequence and may relate to the alteration developed at the Goldlund gold Deposit. The presence of highly scoriaceous and amygdaloidal flows coupled with the increased angularity and size of pyroclastic blocks observed in the Goldlund area suggests that the sequence was shoaling and may have been subaerial in Echo Township.

Elsewhere, mafic metavolcanics occur as small discontinuous units interlayered with metasediments in MacFie and McAree Townships.

Felsic extrusive rocks underlie McAree Township in two separate areas. The larger sequence north of Sandy Beach Lake on Highway 72 is composed of rhyolitic to dacitic pyroclastic rocks with minor autobrecciated and compositionally banded flows. Quartz-phyric tuffs, lapilli-tuffs, and tuff-breccias are poorly sorted and intermixed with several pyritic quartz-sericite schists and sulphide-facies ironstones northwest of Highway 72. The sequence extends eastward to Pickerel Arm of Minnitaki Lake and appears to be in sharp conformable contact with wackes and argillites in that area. These rocks are the southward extension of felsic metavolcanics mapped by Page and Christie (1980).

A second separate area of felsic metavolcanics occurs on Pickerel Arm of Minnitaki Lake and is composed of feldspathic crystal tuffs, laminated tuffs, lapillistones, and tuff-breccias. These rocks are generally heterolithic, well sorted, and often show grading with "tops" to the east. The felsic metavolcanics are interbedded with feldspathic wackes and argillites which gradually become dominant towards the central and southern parts of McAree Township.

This felsic sequence is interpreted to have been deposited subaqueously, possibly by debris flows.

Feldspar-phyric, quartz-feldspar-phyric, and felsite dikes are included within the felsic metavolcanics because the groundmass is usually fine grained to aphanitic and the dikes appear to be related more closely to the extrusive felsic metavolcanics than to any of the felsic granitoid intrusions. The felsic dikes occur throughout the map area but are most heavily concentrated near the Wabigoon Fault where they intrude mafic metavolcanics and are spatially associated with three gold occurrences. In northwestern McAree Township, extremely quartz-phyric felsic dikes (quartz phenocrysts up to 2 cm) intrude metasediments and the calc-alkalic metavolcanics. These dikes are not wide (1 to 3 m) or extensive but are similar to quartz-phyric dikes observed on the Goldlund property to the north.

Metasediments underlie much of McAree Township and are composed predominantly of feldspathic wackes, argillites, pebbly sandstones, derived schists, and metatexites. Most of the wacke units are turbiditic in origin; however, primary structures are poorly preserved. Available facing data indicate the metasediments are tightly folded along Highway 72 and young to the southeast in the Pickerel Arm area. A distinctive staurolite-cordierite-bearing schist is developed along the northern contact with the Sandy Beach Lake Intrusion and can be used as a marker horizon in this area. Based on descriptions from previous workers (Walker and Pettijohn 1971; Hurst 1933), the metasediments in McAree Township are correlative with the Minnitaki Group which is better preserved north of the map area.

Mafic intrusive rocks are gabbroic in composition and intrude the mafic metavolcanics in Avery and MacFie Townships. Gabbros occur as medium- to coarse-grained sill-like intrusions and are often confused with coarse-grained basaltic flows. Intrusive contacts were observed at several locations but gradational contacts with basalts are also common. The large intrusion centred at Cole Lake in the east was seen at two locations where it is a medium-grained gabbro. Ultramafic rocks were not seen in the map area.

Felsic granitoid rocks form the Melgund Lake Stock, the Basket Lake Batholith, the Sandy Beach Lake Intrusion, and the Cross Echo Lake Intrusion. The Melgund Lake Stock varies from a hornblende-bearing diorite to granodiorite with quartz monzonite forming over 80 percent of the intrusion. The rocks are equigranular to porphyritic and generally massive. The intrusion has a narrow metamorphic aureole and appears to be post-tectonic.

The Basket Lake Batholith varies from quartz monzonite to granite with a dioritic to quartz dioritic hybrid zone around the borders. Leucocratic, biotitic quartz monzonite is the major lithology of the pluton and also occurs as dikes that were intruded parallel to the foliation planes in the surrounding mafic metavolcanics. The rocks of the pluton are foliated and lineated and appear to be syntectonic.

The Sandy Beach Lake Intrusion is composed of foliated hornblende-biotite-bearing quartz diorite with minor monzonite. The development of staurolite-cordierite metamorphic mineral assemblages and metatexites in the country rocks attest to the high temperatures associated with this intrusion. A suite of granitic pegmatites and aplites, some of which contain garnet and fibrolitic sillimanite, are developed along the northwestern contact of the intrusion. These rocks are not part of the Sandy Beach Lake Intrusion as previously mapped but have formed by anatexis of the metasediments.

The Cross Echo Lake Stock is exposed in the northwestern corner of the map area. Pink aplite is the major lithology with minor white-weathering tonalite. The intrusion is in sharp contact with the country rock and appears to have been intruded at a higher crustal level than the Sandy Beach Lake Intrusion. Most of the Cross Echo Lake Stock is exposed outside the map area and readers are referred to Satterly (1943) and Page and Christie (1980) for more complete coverage of the stock.

STRUCTURAL GEOLOGY

A major structural feature transecting the map area is the Wabigoon Fault. In MacFie Township the fault is characterized by an east-northeast-trending zone (maximum 400 m wide) of intensely sheared mafic metavolcanics and quartz-feldspar-phyric dikes. A prominent geographical lineament marks the fault's location. In McAree Township the fault is characterized by a braided zone of northeast-trending sheared mafic metavolcanics separated by relatively undeformed rocks. Pervasive carbonate alteration is locally developed along the fault but extensive sulphide mineralization was not observed.

South of the Wabigoon Fault, mafic metavolcanics in MacFie and Avery Townships are generally north or northeast facing. Along the western boundary of Avery Township reliable facings are west to northwest and indicate that folding and faulting has affected this area.

North of the Wabigoon Fault there is abundant evidence of multiple deformations. The most prominent feature is a doubly-plunging structural dome oriented about a northeast-southwest axis in northern McAree Township. The dome is the product of interference of two folding events; a crenulation cleavage developed at outcrop scale indicates that the northeast trend is part of the younger deformational event. Each deformation is associated with a high grade metamorphic event as evidenced by crenulated cordierite and rotated staurolite being overprinted and transposed by undeformed staurolite and cordierite crystals.

The majority of stratigraphic facings north of the Wabigoon Fault are toward the southeast; however, tight isoclinal folding about northeast-trending axes is indicated in the metasediments by occasional facing reversals and changes in dip of bedding. This feature as well as transposition along the northeast-trending cleavage planes makes stratigraphic interpretation very difficult.

ECONOMIC GEOLOGY

Gold mineralization occurs within three environments in the map area:

1. in large quartz veins in sheared and altered mafic metavolcanics
2. in silicified and carbonate altered zones at the apparent intersection of northeast- and east-northeast-trending lineaments
3. in sulphide stringers within iron-rich metasediments

The Midas and Alto Gardner (Figure 012.1) Occurrences are examples of the first type of mineralization where gold (sometimes visible) occurs in quartz veins up to 4 m wide. The veins also contain chalcopyrite, tourmaline, pyrite, and varying amounts of carbonate. The veins are localized in narrow northeast-trending (5 to 15 m wide) intensely sheared mafic metavolcanics locally with feldspar-phyric dikes. Alteration in the wallrock is localized within the shears and consists of pyrite, carbonate, and minor quartz stringers, apparently without significant gold values. The large quartz veins have limited strike length (150 m or less) and have been explored to shallow depths (less than 50 m).

The gold occurrence at the River's Option in McAree Township is similar to both the Midas and Alto-Gardner Occurrences; however, feldspar- and quartz-feldspar-phyric dikes are more abundant and locally auriferous. The role of the felsic dikes in the process of gold mineralization is uncertain but at all three of these occurrences lithologic control appears subordinate to structural control.

The second type of gold environment is best developed in Avery Township where gold is associated with an alteration zone at the intersection of an east-northeast-trending lineament with a northeast-trending lineament (Figure 012.1). Intense silica flooding accompanied by brecciation, pervasive carbonate alteration, and spotty pyritization is hosted by mafic metavolcanics. Assessment reports filed by exploration companies indicate gold is most closely associated with the silicified zone where pyrite is most heavily concentrated.

On Sandy Beach Lake gold occurs in pyrite-pyrrhotite-arsenopyrite stringers hosted by highly metamorphosed laminated magnetite-quartz ironstone. The sulphide stringers occur both conformably with and cross-cutting the laminations. The occurrence is poorly exposed and appears to be unique in the map area.

The potential for undiscovered gold mineralization is good in the map area. The Midas, Alto-Gardner, and River's Occurrences are localized on a structure parallel to the Wabigoon Fault. This subsidiary structure appears to be continuous and gold may occur anywhere along its strike.

In Avery Township a number of silica-carbonate alteration zones were observed at the loci of northeast and east-northeast-trending lineaments. Although none are as intensely altered as the zone described above, none have been previously explored and assays are pending.

Magnetite ironstones are rare in the map area and associated gold with arsenopyrite is known only at the Sandy Beach Lake location. However, several sulphide ironstones and pyritic quartz-sericite schists in the felsic metavolcanics were observed and some are apparently unexplored. Given the amount of gold mineralization in the region, all sulphide occurrences warrant examination.

The Goldlund gold Deposit occurs 1000 m north of the map area and occurs in an altered intrusion. Page (1984) has compiled the general geology and details of the deposit and the reader is referred to Page (1984) for further details. The main volcanic sequence extends into McAree Township and although extensive exploration has failed to yield new discoveries, this area must still be considered favourable for gold mineralization.

Felsic metavolcanics are more extensive than previously recognized in the map area. Several pyritic ironstones and quartz sericite schist zones are intercalated with the felsic metavolcanics and systematic exploration for gold and base metals is warranted.

The extensive granitic pegmatites developed north of the Sandy Beach Lake Intrusion are peraluminous and warrant exploration for rare elements and industrial mineral potential.

The central part of MacFie Township is covered by the extensive Trout-Basket terminal moraine (Zoltai 1961). Parts of the moraine contain reworked sand and gravel deposits which appear to be suitable for road construction.

The late syntectonic to post-tectonic Melgund Lake Stock has several areas which appear to be massive and homogeneous enough to warrant consideration as a building stone.

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013. Proposals for Revision of the Stratigraphy of the Steep Rock Group and the Identification of a 3 Ga Basement Terrane

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INTRODUCTION

The Archean Steep Rock Group, northwestern Ontario, has been well known since the days of Lawson (1912). Recent re-examination of the group has confirmed that it lies unconformably (Jolliffe 1955, 1966) upon an older 3 Ga basement tonalite complex. It may be possible to identify fragments of this basement complex across much of northwestern Ontario, forming remnants of what may have been the early continental nucleus of central North America.

STEEP ROCK STRATIGRAPHY

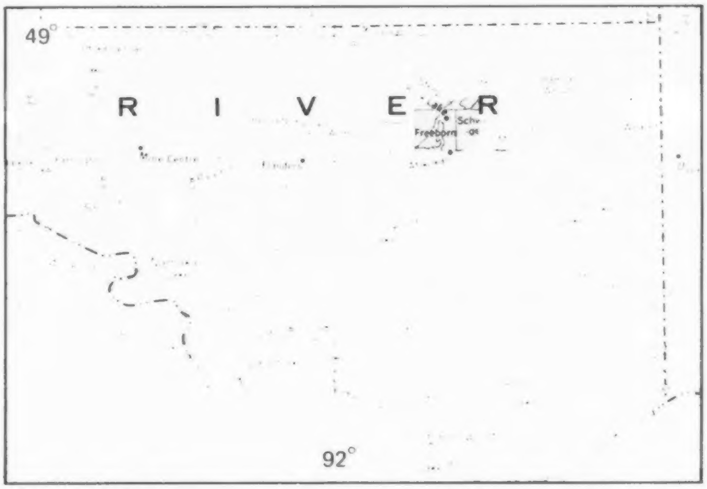
The Steep Rock Group, in our proposed revision of the stratigraphic section, comprises five formations: Basal Clastic Carbonate, Ore Zone, Ash Rock, and, provisionally, Metavolcanics (Table 013.1). The Basal Clastic Formation is mainly a conglomerate (0 to 150 m thick) unconformably overlying the Marmion Complex, which is massive terrane of tonalite-tonalite gneiss and mafic dikes, circa 3 Ga old (Davis and Jackson 1985).

Overlying the Basal Clastic Formation is the Carbonate Formation (0 to 500 m thick) which contains diverse stromatolitic morphologies. Above this is the Ore Zone Formation (100 to 400 m thick), divided into a lower manganiferous Paint Rock Member and an upper Goethite Member. Overlying the Ore Zone Formation is the Ash Rock Formation, dominated by high-magnesium pyroclastic rocks. In contact with the Ash Rock Formation is the Metavolcanics Formation. The nature of the contact is not known. There has clearly been movement along the contact, but it is not clear if this constitutes a major structural break or a minor displacement. The Metavolcanics Formation is thus only provisionally included with the Steep Rock Group.

STRATIGRAPHIC SETTING OF THE STEEP ROCK AND LUMBY LAKE BELTS

Various authors (Edwards and Davis 1986; Wood *et al.* 1986; Beakhouse 1985; Edwards 1985; Thurston and Davis 1985; Martin 1983; Ermanovics and Davison 1976; Shklanka 1972; and Roussel 1965) have discussed the nature of the relationship between supracrustal greenstone belts and tonalite-gneiss complexes. In the N.W. Superior Province, Roussel (1965) and Ermanovics and Davison (1976) discussed an unconformity in the Cross Lake area of Manitoba, where conglomerate overlies granite gneiss. In northwestern Ontario, Wood *et al.* (1986) outlined several successions where intra-greenstone belt unconformities exist (North Spirit Lake, Eyapamikama Lake, Red Lake and Uchi Lake). They considered that in the Sachigo Subprovince, an older greenstone succession, including mature sediments and komatiites, was either unconformably or disconformably overlain by a younger succession of immature sediments and bimodal volcanic rocks.

This older greenstone succession may be, at least in part, circa 2900 to 3000 Ma old (Wood *et al.* 1986). This contrasts with a variety of 2700 Ma dates obtained from younger greenstone successions in northwestern Ontario. The overall stratigraphic history



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

TABLE 013.1: COMPARISON OF STEEP ROCK GROUP NOMENCLATURE.

Smyth, 1891	Lawson, 1912	Moore, 1939	Jolliffe, 1966	Shklanka, 1972	Wilks & Nisbet, 1986
Steep Rock Succession	Steep Rock Succession	Steep Rock Group	Steep Rock Group	Steep Rock Group	
Dark grey slate	----	----	----	----	----
Agglomerate	----	----	----	----	----
Greenstones	----	----	----	----	----
Upper conglomerate	----	----	----	----	----
Upper calcareous greenschist	----	----	Interbedded flows tuffs & sediments	----	Witch Bay Metavolcanics
Interbedded Crystalline Traps	Interbedded crystalline	Ferruginous Carbonate Fm	Ashrock Fm	Ashrock Fm	Dismal Ashrock Fm
Ferruginous Fm	Ferruginous Fm	Lavas, Dikes, Pyroclastic Rocks	Ore Zone Fm	Pyritic Fm	Jolliffe Ore Zone
Lower Limestone	Lower Limestone	Limestone	Limestone & Dolomite	Dolomite Fm	Mosher Carbonate
Conglomerate	Conglomerate	Conglomerate	Conglomerate Fm	Conglomerate Fm	Wagita Basal Conglomerate

of the greenstone successions of northwestern Ontario is thus very complex. Some rocks are 2900 Ma or older, but a younger suite of 2700 to 2800 Ma age also exists.

The successions north of Atikokan may be critical to unravelling this complexity. In the Lumby Lake area, Davis and Jackson (1985) have identified a 2990 to 3000 Ma greenstone suite. What then is the age of the Steep Rock Group? Davis and Jackson (1985) have shown that at least part of the Marmion Complex is approximately 3000 Ma old. A sample from the tonalite gneiss gave an age of 2991 Ma, while massive tonalite is 2919 Ma. To the northeast of the Steeprock succession, rhyolites from the Lumby Lake greenstones gave U-Pb zircon results in the range 2990-2999 Ma. If the Steep Rock and Lumby Lake successions are correlated, then the implication is that the Steep Rock Group is the same age.

However, the correlation between the Steep Rock and Lumby Lake successions is uncertain, and circumstantial evidence argues against it. Firstly, the nature of the unconformity surface above the Marmion Complex and below the Steep Rock group would suggest a relatively mature erosional surface, cut into by minor channels and valleys, but not a source of massively thick clastic deposits. The very short time period between the age of the tonalitic gneiss of the Marmion Complex and the age of the Lumby Lake succession would argue, though not strongly, that in order for a fairly mature erosional surface to develop, the Steep Rock Group must be younger than the Lumby Lake suite. Secondly, the metamorphic grade of the Lumby Lake suite is much higher than the grade of the Steep Rock Group.

Neither one of these arguments are strong; further mapping is needed. Furthermore, the missing clastics derived from the Marmion terrane may now be in the Quetico Subprovince, unrecognized. However, it is possible that parts of the Marmion Complex, together with the Lumby Lake succession, define a circa 3 Ga continental surface which was eroded and on which was deposited the Steep Rock Group. Alternatively, the Marmion Complex alone may constitute the basement which was subjected to rapid erosion and planation of approximately 3 Ga and upon which both the Steep Rock Group and Lumby Lake successions were deposited.

There are interesting analogies between this succession and that in the Belingwe belt, Zimbabwe, the latter of which contains circa 2.9 and 2.7 Ga greenstone strata, both deposited on an older (3 to 3.5 Ga) basement of tonalitic gneiss (Martin 1983).

THE EXTENT OF THE BASEMENT – AN ANCIENT WESTERN SUPERIOR MICROCONTINENT?

The evidence for older basement rocks in the Wabigoon Subprovince has been discussed by Thurston and Davis (1985). In northwestern Ontario, in general, 3 Ga gneisses are widely known. They have been reported by Harris and Goodwin (1976), and Krogh *et al.* (1976) from the English River Subprovince, and by Corfu *et al.* (1984) from tonalitic clasts in conglomerates in the Sachigo Subprovince. Davis *et al.* (1986) pointed to these dates as evidence for the existence of a pre-Kenoran continent. A 3 Ga terrane also occurs near the south margin of the English River Subprovince, in the Lake of the Woods area (Clark *et al.* 1981), and in the Pikwitonei granulite terrane (Ermanovics and Davison 1976). This abundant, though fragmentary, evidence would suggest that much 3 Ga continental crust did exist in the area. What is not clear is whether this crust represents a variety of very different pieces which accidently collided together in a number of events, as suggested by Card (1986), or if the crust was originally a coherent cratonic unit, as suggested by Edwards (1985) and Davis *et al.* (1986). The similarity of the various 3 Ga dates suggests, though weakly, that the latter was the case, and that an early continental nucleus - perhaps we should call it 'Lawsonia' - is preserved in northwestern Ontario and eastern Manitoba.

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014. Geological and Geophysical Studies in the Lac des Iles Area, District of Thunder Bay

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INTRODUCTION

This section briefly introduces the following summaries which present preliminary results of integrated geological and geophysical field activities in the Lac des Iles area of northwestern Ontario. These studies form part of a program of investigation of Archean mafic and ultramafic intrusions in northwestern Ontario which was initiated in 1984. A major aim of the program is an assessment of the mineral potential of mafic and ultramafic rocks, especially for platinum group elements (PGE). The current study of the Lac des Iles area is a continuation of detailed mapping of the Lac des Iles Complex, which began in 1985.

The Lac des Iles area is centred approximately 80 km northwest of Thunder Bay. Mafic intrusions within the area provide several exploration targets for PGE. The Lac des Iles Complex, the largest mafic intrusion in the area, contains the Boston Bay Mines Limited's, Roby Zone Deposit. To date, 20.4 million tonnes of gabbro containing palladium (Pd) and platinum (Pt) with an average grade of 6.34 grams per tonne PGE have been outlined in the deposit (The Northern Miner, Volume 62, October 21, p.27, 1976; Canadian Mines Handbook 1976-1977, p.313-314). Studies described here indicate that palladium and platinum mineralization is not restricted to the Roby Zone and suggests that other intrusions in the area have potential for PGE mineralization. Specific exploration targets are recommended based on this work.

The individual studies making up the Ontario Geological Survey's program in the Lac des Iles area are described in more detail in subsequent summaries. These studies include:

1. Regional 1:50 000 scale mapping of the Lac des Iles area (NTS 52 H/4 and part of 52 H/5) by the author and A.R. Smith. This mapping provides a regional lithologic, tectonic, and metallogenetic framework encompassing both the major intrusions in the area and the host rocks.
2. Detailed 1:15 840 scale mapping of the Tib Gabbro, located 15 km northwest of the Lac des Iles Complex, was completed by A.R. Smith and the author. The Tib Gabbro is a well preserved, layered intrusion which is host to sulphide mineralization with PGE concentrations.
3. Gravity studies of mafic and ultramafic intrusions in the Lac des Iles area were carried out by V.K. Gupta (Geophysicist, Geophysics-Geochemistry Section, Ontario Geological Survey, Toronto). This survey included both regional coverage of the area (NTS sheets 52 H/4 and part of 52 H/5), and detailed studies over the mafic-ultramafic intrusions. The gravity survey will enable the form and dimensions of the mafic intrusions to be modeled, and will provide constraints on the regional structure.
4. Detailed mapping, as a preliminary phase of petrologic and metallogenetic studies on the ultramafic rocks of the Lac des Iles complex, was carried out by E. Linhardt of the University of Munich. This work was done under a volunteer agreement between the Ontario Geological Survey and the University of Munich. The work will form the basis of a Ph.D. Thesis by E. Linhardt.
5. Detailed 1:2400 scale mapping of the Roby Zone was initiated by J.M. Sweeny and the author. This work will form the basis of petrologic and metallogenetic studies of the Roby Zone by J.M. Sweeny and A.D. Edgar at the University of Western Ontario. These studies are funded by the Ontario Geoscience Research Grant Program.
6. A feasibility study, involving the use of humus as a medium for geochemical prospecting for PGE, was commenced by J.A.C. Fortescue and J.R. Webb, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto. In this study, humus samples were collected from a line 250 m in length across the Roby Zone.

In addition to the above projects, Ontario Geological Survey field support and geological input was also given to two projects in the area funded by the Geoscience Research Fund Grant Program. H.C. Palmer (Professor, Department of Geophysics, University of Western Ontario, London) is investigating the rock magnetism of the Lac des Iles Complex and other Archean mafic intrusions. This study involves both magnetic susceptibility anisotropy and paleomagnetic measurements. G. Brugemann (Postdoctoral Fellow) and A.J. Naldrett (Professor, Department of Geology, University of Toronto) are investigating the PGE geochemistry of silicate phases from mafic intrusions in the Lac des Iles area.

015. Regional Geology of the Lac des Iles Area, District of Thunder Bay

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INTRODUCTION

This summary reports on the results of regional mapping in the Lac des Iles area (NTS 52 H/4 and part of 52 H/5) at a scale of 1:50 000. The map area encompasses several Archean mafic to ultramafic intrusions with potential for platinum group element (PGE) mineralization. The mapping provides a regional framework for understanding the lithologic, tectonic, and metallogenetic evolution of these intrusions. Results of the mapping include new data on PGE potential of the intrusions, and the delineation of a previously unreported mafic intrusion.

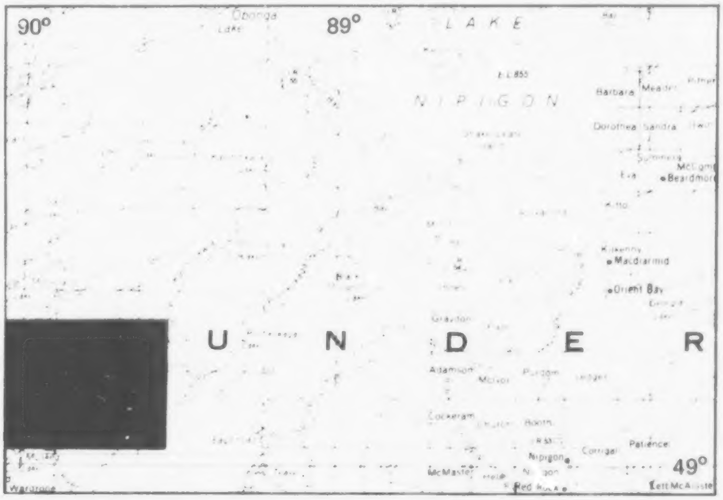
The Lac des Iles area is centred approximately 80 km northwest of Thunder Bay. Road access to most of the area is provided by Great Lakes Pulp and Paper Company logging roads in the Dog River area. The main access road proceeds north from Highway 17, approximately 10 km west of Raith, to Great Lakes Pulp and Paper Company Camp 234. The southeastern part of the area has no road access and is accessible by helicopter and float-equipped aircraft.

MINERAL EXPLORATION

Economic interest in the area was initially for copper-nickel sulphide mineralization in ultramafic and mafic rocks. More recently, exploration has centred on PGE mineralization. Most of the exploration work has focused on the Lac des Iles Complex which is the largest intrusion in the area and is host to significant palladium and platinum mineralization. The Tib Gabbro, which is the second largest mafic intrusion in the area, has also been a centre of exploration activity. Details of the exploration history in these areas are reported by Sutcliffe and Sweeny (1986) and by Smith and Sutcliffe (this volume). In this summary, only a brief synopsis of exploration work will be made. Information on exploration history reported here is, unless otherwise stated, taken from the Assessment Files Research Office, Ontario Geological Survey, Toronto.

Exploration interest in the area began in the late 1950s, following airborne geophysical surveys which indicated magnetic anomalies associated with the Lac des Iles Complex. Widespread copper-nickel mineralization was discovered south of Lac des Iles by prospectors W. Baker and G. Moore in 1963. These claims were acquired by Gunnex Limited and subsequently optioned by Anaconda American Brass Limited. Work by these companies, between 1963 and 1966, resulted in the delineation and investigation of eight mineralized zones and the recognition of significant PGE concentrations. The claims, however, were allowed to lapse. K. Kuhner staked the ground in 1973 and the property was acquired by Boston Bay Mines Limited in 1974. Texasgulf Canada Limited optioned the property in 1975 and with Boston Bay Mines Limited carried out an extensive exploration program in 1975 and 1976. This work included diamond-drilling 119 holes (approximately 19 000 m) and resulted in the delineation of a zone of palladium and platinum mineralization named the Roby Zone. Texasgulf Canada Limited dropped the property in mid-1976.

Active exploration in 1975 and 1976 stimulated work on other mafic intrusions in the area. During this time, several companies conducted geological and geophysical surveys and diamond drilling to delineate and evaluate sulphide zones in the Tib Gabbro. Anomalous PGE concentrations were recognized in association with a zone of sulphide mineralization at



LOCATION MAP   Scale : 1:1 584 000 or 1 inch to 25 miles

the southern margin of that body. This zone is known as the Kuhner Occurrence.

In other work during 1975 and 1976, Combined Metal Mines Limited, in conjunction with Goldray Mines Limited, completed ground magnetic and electromagnetic surveys southwest of Emey Lake. Osisko Lake Mines Limited and Joliet-Quebec Mines Limited completed ground electromagnetic surveys on a claim group optioned from Boston Bay Mines Limited in the Shelby Lake area. Texasgulf Canada Limited completed airborne geophysical surveys in the area including, and southwest of, the Lac des Isles Complex. Nomad Mines Limited and White Star Copper Mines Limited diamond-drilled four holes (173 m) in a zone of sulphide mineralization in mafic and ultramafic rocks at Demars Lake.

In 1985 and 1986, renewed interest in PGE resulted in extensive staking of mafic and ultramafic rocks in the area. In 1986, the Platinum Group Limited, a private, federally chartered company which is 90 percent owned by Boston Bay Mines Limited, initiated a program of diamond drilling, trenching, and bulk sampling to evaluate the feasibility of developing an open-pit mine on the Roby Zone (The Northern Miner, 1986, Volume 72, Number 4, p.1). In 1986, several other companies initiated exploration work to investigate the PGE potential of the area.

GENERAL GEOLOGY

Previous mapping of the area is primarily the reconnaissance mapping and compilation by Sage *et al.* (1974). Parts of the area have been mapped by Pye (1968), Kaye (1966, 1969), Milne (1964), and Sutcliffe and Sweeny (1986).

Archean mafic intrusions, in the Lac des Iles area, form part of an east-northeast-trending linear zone of mafic plutons which extends from Atikokan to Lake Nipigon. This zone parallels the boundary between the Wabigoon and Quetico Subprovinces. Within the map area, most of the rocks are within the Wabigoon Subprovince; however, the subprovince boundary passes through the southeastern part of the area.

In a more detailed sense, mafic to ultramafic intrusions in the Lac des Iles area form a circular structure approximately 30 km in diameter (Figure 015.1). The intrusions, which together have broad lithologic and metallogenetic similarities, are late tectonic, and intrude granitoid host rocks. The intrusions are tholeiitic in affinity, and contain phases ranging from ultramafic peridotitic and pyroxenitic cumulates to magnesian gabbronorite and iron-rich gabbro. Hybrid marginal zones, consisting of hornblendite intruded by hornblende diorite, are common to many of the intrusions and are interpreted to be due to contamination of mafic magma by a granitoid component. Most of the intrusions have well preserved mineralogy and are not significantly deformed or altered.

Granitoid rocks, into which these intrusions were emplaced, consist of predominantly gneissic tonalite. The mafic intrusions are interpreted, on the basis of field relations, to be comagmatic with a suite of hornblende tonalite to biotite granite which occupies the centre of the circular configuration. Compositions of some of the younger granitoids reflect magma mixing between granitic melt and mafic magma.

The Lac des Iles Complex consists of an ultramafic intrusion centred on Lac des Iles, and a gabbroic intrusion south of the lake. The gabbroic rocks are host to the most important zones of palladium-platinum mineralization found so far in the area; however, occurrences of PGE have also been identified in the ultramafic portion of the complex (Sutcliffe and Sweeny 1986; Linhardt and Sutcliffe, this volume). In the current regional mapping project, mafic rocks at the southern end of the complex (South of 49°07'30") were investigated. These rocks, which were previously mapped by Kaye (1969), cause a pronounced aeromagnetic high which extends southwest of Lac des Iles (ODM-GSC 1962). The present mapping indicates that mafic rocks in this area are less extensive than previously indicated and that most of the magnetic anomaly is underlain by dioritic rocks. The hornblende gabbro phase of the Lac des Iles Complex mapped by Sutcliffe and Sweeny (1986) grades, south of Hasson Lake, into hornblende diorite to quartz diorite with less than 35 percent ferromagnesian minerals. The diorite locally contains numerous inclusions and blocks of coarse hornblendite and medium-grained mafic diorite, and is similar to dioritic rocks on the western margin of the Complex at Lac des Iles. The dioritic rocks intrude gneissic biotite tonalite on the northwestern side of the structure and grade into biotite-hornblende quartz diorite and tonalite on the southeastern side.

The Tib Gabbro, which is the second largest mafic intrusion in the area, is also host to sulphide mineral occurrences with anomalous PGE concentrations. The intrusion was mapped in detail during 1986 and is discussed by Smith and Sutcliffe (this volume).

The Demars Lake Intrusion is a small, approximately 1 km wide, elliptical plug on the southwestern shore of Demars Lake, and is intrusive into gneissic tonalite. The body consists of an ultramafic core of medium-grained websterite, with a marginal zone of hornblende gabbro and hornblende pyroxenite. The websterite of the Demars Lake intrusion contains cumulus orthopyroxene and clinopyroxene with intercumulus plagioclase, and is very similar to the websterite phase of the Lac des Iles Complex. Disseminated copper-nickel sulphide mineralization, with significant palladium and platinum concentrations, occurs in the Demars Intrusion (*see* section on Economic Geology).

Gabbroic rocks at Wakinoo Lake, on the southern boundary of the map area, were only briefly investigated. This intrusion appears to consist predominantly of medium-grained hornblende gabbro, and is commonly extensively saussuritized and epidotized. The Legris Lake Intrusion was not investigated during this study.

Mafic intrusions at Taman Lake, and on the Dog River, had previously been defined largely on the basis of pronounced aeromagnetic anomalies (ODM-GSC 1962). These intrusions consist of hornblende pyroxenite, to hornblende melagabbronorite, with

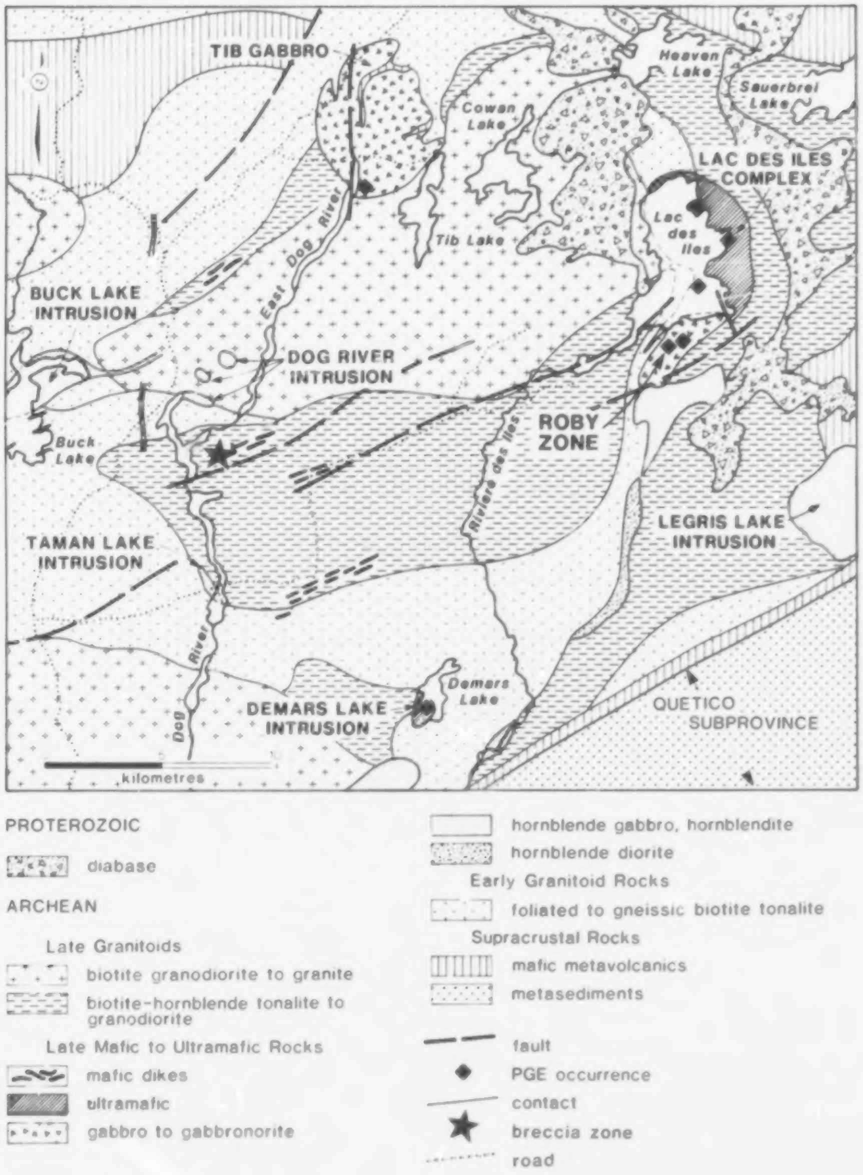

TIB GABBRO
Heaven Lake
Sauerbrei Lake
Cowan Lake
LAC DES ILES COMPLEX
Lac des Iles
Tib Lake
East Dog River
BUCK LAKE INTRUSION
DOG RIVER INTRUSION
ROBY ZONE
Buck Lake
Rivière des Iles
TAMAN LAKE INTRUSION
LEGRIS LAKE INTRUSION
Dog River
Demars Lake
DEMARS LAKE INTRUSION
QUETICO SUBPROVINCE
kilometres
PROTEROZOIC
diabase
ARCHEAN
Late Granitoids
biotite granodiorite to granite
biotite-hornblende tonalite to granodiorite
Late Mafic to Ultramafic Rocks
mafic dikes
ultramafic
gabbro to gabbronorite
hornblende gabbro, hornblendite
hornblende diorite
Early Granitoid Rocks
foliated to gneissic biotite tonalite
Supracrustal Rocks
mafic metavolcanics
metasediments
fault
PGE occurrence
contact
breccia zone
road

Figure 015.1. Geological sketch map of the Lac des Iles area showing known Platinum-Group-Elements (PGE) Occurrences.

marginal clinopyroxene-hornblende dioritic to gabbroic phases. In the pyroxenites and melagabbronorite phases, clinopyroxene and less common orthopyroxene occur as cumulus grains up to 2 mm across, with intercumulus plagioclase and large poikilitic hornblende up to 2 cm across. The extensive development of poikilitic hornblende and the presence of marginal zones of hornblende diorite is considered to be a result of the hybridization of mafic magma by assimilation of granitoid country rocks. Both of these intrusions are less extensive than expected from their aeromagnetic expressions. Furthermore, the Dog River Intrusion consists of several isolated occurrences of mafic rocks surrounded by granitoids. These relationships suggest that the Dog River and Taman Lake Intrusions may be partially buried by a granitoid cover. This model is to be investigated by gravity studies.

The Buck Lake Intrusion is a previously unrecognized mafic to ultramafic intrusion outcropping on the northern side of Buck Lake. The intrusion is elliptical in plan with an east-west elongation and a cross-sectional area of approximately 5 km^2. A dike-like body, striking at 70°, extends east from the intrusion and consists of medium-grained, fresh hornblende gabbro. The main intrusion consists of phases ranging from hornblende gabbro and gabbronorite, to clinopyroxenite and hornblende clinopyroxenite. The hornblende gabbro is the dominant lithology, and is typically medium grained, with local pegmatoidal patches containing biotite and quartz. Ultramafic rocks in the intrusion contain variable proportions of hornblende and clinopyroxene. Breccia zones, in which leucocratic phases intrude melanocratic phases, ranging in composition from gabbro to pyroxenite, are common in the intrusion, especially along the northwestern shore of Buck Lake. These textures are similar to those observed on the margin of the Lac des Iles Complex. Minor chalcopyrite, pyrite, and pyrrhotite mineralization were observed in the Buck Lake Intrusion, but, to date, no anomalous PGE concentrations have been detected by assays.

Mafic to ultramafic intrusions in the Lac des Iles area are emplaced into older gneissic tonalitic host rocks. In general, the gneissic tonalite occurs around the periphery of the circular structure defined by the mafic intrusions. The gneissic tonalite is fine to medium grained, and is recrystallized, with approximately 5 percent biotite as the predominant ferromagnesian mineral. Hornblende is locally present, adjacent to zones of amphibolite enclaves. The tonalite is strongly foliated to gneissic, with gneissosity primarily defined by layers of ubiquitous leucotonalite mobilizate. Other phases associated with the gneissic tonalite include medium-grained hornblende diorite to quartz diorite, and granite to granitic pegmatite veins and dikes.

Two younger granitoid phases occupy the central core of the circular structure and are essentially surrounded by the mafic intrusions. These include a foliated biotite-hornblende tonalite pluton, in the southern part of the core, and a foliated to massive pluton of granodioritic to granitic composition, in the northern part.

The biotite-hornblende tonalite is medium to coarse grained, and weakly to strongly foliated. Biotite and hornblende, in variable proportions, constitute up to 20 percent of the rock; however, coarse, blocky hornblende grains up to 1 cm across are a characteristic feature of the phase. The biotite-hornblende tonalite is interpreted to be contemporaneous with mafic magmatism in the Lac des Iles area. This interpretation is based on textures suggesting the coexistence of two magmas within the pluton. Furthermore, the textures suggest that the two magmas mixed to produce the hornblende tonalite. These textures include: "net-veined" mafic to intermediate dikes, which discordantly intrude foliated tonalite, and are back-veined by the tonalite; rounded to cuspate mafic inclusions in tonalite, which can be traced into disaggregated "net-vein" dikes; and zones of hybrid compositions, characterized by development of coarse (2 to 3 cm), skeletal hornblende along the interface between mafic and felsic phases.

The crystallization of skeletal hornblende is interpreted to be a result of supercooling due to magma mixing. The presence of skeletal to blocky hornblende, throughout the tonalite pluton, also suggests that magma mixing may have produced much of the mafic material in the granitoids. Similar skeletal textures also occur in hornblende-rich lithologies around the margin of the Lac des Iles Complex, and support a process of contamination through magma mixing at the margins of the major mafic intrusions, as well as adjacent to the dike rocks.

The granodiorite to granite pluton, occupying the northern part of the central core, is intrusive into gneissic tonalite and hornblende tonalite. The pluton is characterized by medium-grained, equigranular, massive to weakly foliated, granite to granodiorite with approximately 5 percent biotite. A border phase of granodiorite, with distinctive 1 to 2 cm microcline megacrysts, occurs along the northern and southern margins of the pluton.

Fine- to medium-grained dike rocks, ranging in composition from mafic amphibolite to diorite, intrude all of the Archean lithologies in the area, including rocks of the Lac des Iles Complex. These dikes commonly trend at approximately 70°, and are especially common in the hornblende tonalite where they display the previously described magma mixing textures. The widespread distribution of the dikes, in the central part of the area, suggests that mafic magma may have underplated the granitoid rocks.

A distinctive breccia zone, with dimensions of approximately 100 by 300 m, crosscuts the hornblende tonalite east of the Dog River. The breccia consists of subrounded fragments of tonalite, with 3 to 4 cm thick sericitic and silicified alteration rinds, in a matrix consisting of fine-grained, comminuted, and altered felsic material. Rounded, irregular, mafic clots, up to 0.5 m in diameter, are locally present interstitial to the tonalite fragments. Several quartz-feldspar porphyry dikes intrude the breccia.

The breccia is interpreted to represent an explosive degassing of the magma chamber. This process is thought to provide further evidence for the underplating of granitic magma by mafic magma. Explosive devolatilization is an expected consequence of the cooling of such a two magma system (Rice 1985).

The Archean rocks in the area are intruded by diabase sheets and dikes of late Proterozoic age. The diabase is typically medium grained, however, aphanitic, polygonally fractured chill margins are locally observed. Pegmatitic patches are developed toward the top of the diabase sheets, while ophitic textures characterize the lower parts of the sheets. A north-trending diabase dike was traced for several kilometres in the western part of the area, in the vicinity of the Dog River.

STRUCTURAL GEOLOGY

The regional structure of the map area reflects the superimposition of the circular configuration of mafic-ultramafic intrusions on older linear trends, associated with the Wabigoon-Quetico Subprovince boundary zone.

The Subprovince boundary is marked by an east-northeast-trending zone of deformation, several kilometres wide, which is characterized by southeast dips and a well developed southeast-trending lineation. The deformation affects both granitoid and supracrustal rocks in the zone. A similar style of deformation characterizes narrow fault zones, which run parallel to the Subprovince boundary in the central part of the map area. These zones have southeast dips, ranging from 25° to 80°, and are locally associated with mylonitization of the granitoid rocks.

A set of faults, trending approximately north-south, is locally recognized on the basis of offsets of lithological units, such as the Tib Gabbro, and by minor mylonitization and fracturing. This set of faults may have influenced the course of the Dog River and Rivière des Iles.

The circular configuration, defined by the mafic intrusions, is supported by the distribution of granitoid phases (i.e. the gneissic tonalite phase occurs around the periphery of the structure and the younger plutons occupy the core). The positions of the individual mafic intrusions, however, appears to be partially controlled by the east-northeast-trending deformation zones. This fracture set apparently influences the orientation of mafic dikes and some larger bodies, such as the Buck Lake Intrusion. A preliminary interpretation of gravity data indicates that the gravity anomaly maxima, in most intrusions, are coincident with major rivers and/or north-south faults (V. Gupta, Geophysicist, Ontario Geological Survey, Toronto, personal communication, 1986). This suggests that the locations of mafic intrusions are determined by both the north-trending fracture set and the east-northeast-trending fault zones.

As a working hypothesis, it is suggested that the overall structure of the igneous province reflects underplating of pre-existing crust by mantle-derived magma. Some of this magma rose to higher levels along fracture sets in the older crust to form the presently exposed mafic intrusions. In the centre of the structure, crustal melting and magma mixing resulted in the generation of the late granitoid rocks.

ECONOMIC GEOLOGY

Details of PGE mineralization at the Roby Zone, and occurrences within ultramafic rocks of the Lac des Iles Complex and Tib Gabbro, are discussed in other summaries in this volume. In this section, emphasis is placed on summarizing some of the regional lithological controls on PGE occurrences. Analyses were made by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

Mineralization at the Roby Zone, of the Lac des Iles Complex, is contained within gabbroic phases. Important processes in the concentration of PGE appear to have been magma mixing and volatile activity. Sulphides mineralization with significant PGE concentrations, however, occurs in mafic and ultramafic rocks in areas removed from the Roby Zone. This suggests that PGE were concentrated at several stages in the evolution of the mafic magmas within the area.

Sutcliffe and Sweeny (1985) reported several occurrences of sulphide mineralization with significant PGE concentrations (up to 870 ppb Pt, 1170 ppb Pd) from gabbronorite and websterite in the ultramafic rocks at Lac des Iles. The potential for PGE mineralization in the ultramafic part of the Lac des Iles Complex has been confirmed by detailed mapping of the ultramafic rocks and the documentation of further sulphide mineral occurrences with up to 2200 ppb Pd, 350 ppb Pt and 220 ppb Au (*see* Linhardt and Sutcliffe, this volume). This type of mineralization appears to occur in stratiform layers, and is generally associated with more fractionated websterite to gabbronorite phases of the ultramafic intrusion. The grade of PGE mineralization is relatively independent of the concentration of sulphide mineralization, which may be less than 1 percent of the rock.

Websterite to gabbronorite, with PGE associated with minor sulphide mineralization, is also present in the Demars Lake Intrusion. A sample from the sulphide mineral showing south of Demars Lake, with approximately 1 percent chalcopyrite and pyrrhotite, was analyzed and found to contain 1150 ppb Pd, 180 ppb Pt and 80 ppb Au. These were the highest values obtained for PGE, by the field party, from outside of the Lac des Iles Complex.

Anomalous concentrations of PGE were identified in coarse-grained gabbroic rocks from the southern margin of the Tib Gabbro. These occurrences (*see* Smith and Sutcliffe, this volume) are related to processes of localized volatile activity and, possibly, to magma mixing within the intrusion. The mappable igneous stratigraphy within the Tib Gabbro enables favourable horizons for mineralization to be traced laterally.

In summary, PGE mineralization occurs at several fractionation stages of the Lac des Iles magmas. Key geological features in recognizing potential PGE mineralization include: the identification of zones of magma mixing, the presence of coarse-grained or pegmatitic rocks, and the presence of magmatic sulphide mineralization.

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016. Geology of the Tib Gabbro, Lac des Iles Area, District of Thunder Bay

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INTRODUCTION

The Tib Gabbro is a well-preserved, Archean, layered mafic intrusion located in the Wabigoon Subprovince, 95 km north-northwest of Thunder Bay. This report is a summary of the geology, which was mapped during 1986 at a scale of 1:15 840 (1 inch to 1/4 mile). This project forms part of an integrated program investigating mafic and ultramafic intrusions in the Wabigoon Subprovince.

The Tib Gabbro is accessible by road from Thunder Bay via the Great Lakes Pulp and Paper company logging roads extending north-northeastwards from the Trans-Canada Highway 17 through Great Lakes Camp 234. Logging roads traverse the south central and northwestern portions of the intrusion. The East Dog River and a few small lakes within the area are accessible by short portage routes from the logging roads.

The Tib Gabbro is characterized by fresh primary igneous mineralogy and well-developed igneous layering, with only minor zones of deformation and alteration. The intrusion contains anomalous amounts of platinum group element (PGE) mineralization, and, due to the well-preserved igneous stratigraphy, provides an ideal situation to study processes of fractionation and PGE concentration.

MINERAL EXPLORATION

Economic interest in the Tib Gabbro has been mainly for copper, nickel, and platinum group elements mineralization.

Information on mineral exploration reported here, unless otherwise indicated, is taken from the Assessment Files Research Office, Ontario Geological Survey, Toronto. Exploration activities on the intrusion reached a peak in the middle 1970s, at the same time that Texasgulf Canada Limited and Boston Bay Mines Limited were actively exploring claims in the nearby Lac des Iles Complex for PGE. Prior to 1972, minor claim staking and trenching were reported (Kaye 1966).

In 1972, Tex-Sol Explorations Limited carried out electromagnetic and magnetometer surveys on 24 claims occupying the southwestern part of the intrusion. The purpose of this program was to evaluate two nickel-copper sulphide occurrences in gabbronorite. One of these sulphide mineral occurrences was investigated in 1975 by K.C. Kuhner and J.E. Nelson. A single drillhole (150 m long) was completed on a two-claim group centred on the Kuhner Occurrence at the southern end of the intrusion. Anomalous PGE, nickel, copper, and gold values were obtained from assays of pyroxenite with disseminated sulphide mineralization.

A group of 14 claims in the east central part of the intrusion was evaluated in 1975 by Sandhurst Mines Limited. Preliminary geophysical surveys (ground electromagnetic and magnetic) outlined a number of conductors and magnetic anomalies. Also in 1975, exploration work was completed by E.W. Bazinet on 12 claims (Bregman-Mourin claim group) located north of Coon's Lake. A V.L.F. electromagneter survey located a number of conductors, and a magnetometer survey outlined a series of magnetic highs corresponding to layering within the intrusion.

Geological mapping was carried out in 1976 by Michael Ogden on 20 claims (held by R.P. Mackay) in the northwestern part of the intrusion. Mapping served to outline a few sulphide mineral-bearing zones. In the same year, Steppingstone Explorations Limited conducted a drilling program (four diamond-drill holes totaling 320 m) on three claims situated northeast of Coon's Lake.

In 1978, rocks within a single claim located in the southeastern corner of the Tib Gabbro were tested by a diamond-drill hole (153 m long). This work, completed by J. Kondrat, detected sulphide mineral-bearing lithologies.

The most recent exploration work within the Tib Gabbro was completed by Westmin Resources Limited in 1982. Fourteen claims located along the southern edge of the intrusion were evaluated by geological mapping, a soil geochemical survey, and a magnetometer survey. This work delineated a sulphide mineral-bearing pegmatitic horizon extending eastward from the Kuhner Occurrence.

GENERAL GEOLOGY

Initial geological mapping of the Tib Gabbro by Kaye (1966) delineated the approximate extent of the intrusion. Subsequent to this, the area was included in 1:126 720 (1 inch to 2 mile) scale reconnaissance mapping by Sage *et al.* (1974).

The intrusion (Figure 016.1) is an oval-shaped body with an approximate exposed area of 25 km^2. Layer attitudes and outcrop exposure suggest emplacement in a funnel-shaped configuration into the surrounding granitoids, with later tilting to the northeast. The southwestern part of the gabbro, therefore, represents the base of the exposed section.

The Tib Gabbro can be divided into four zones on the basis of observed lithological characteristics. A Border Zone of coarse-grained mafic rocks forms most of the outer margin of the intrusion. Other zones, proceding from southwest to northeast, are here termed the Lower Zone, Middle Zone, and Upper Zone. The lower two zones probably represent distinct magma pulses which crystallized from the base upwards. These zones are characterized by an evolving cumulate mineral sequence. This sequence results in a mappable igneous stratigraphy with pyroxene cumulates near the base and fractionated gabbro at the top. The Upper Zone consists of hornblende gabbronorite and is not well layered.

The Border Zone is of variable thickness (50 to 150 m) and is continuous around the northwestern,

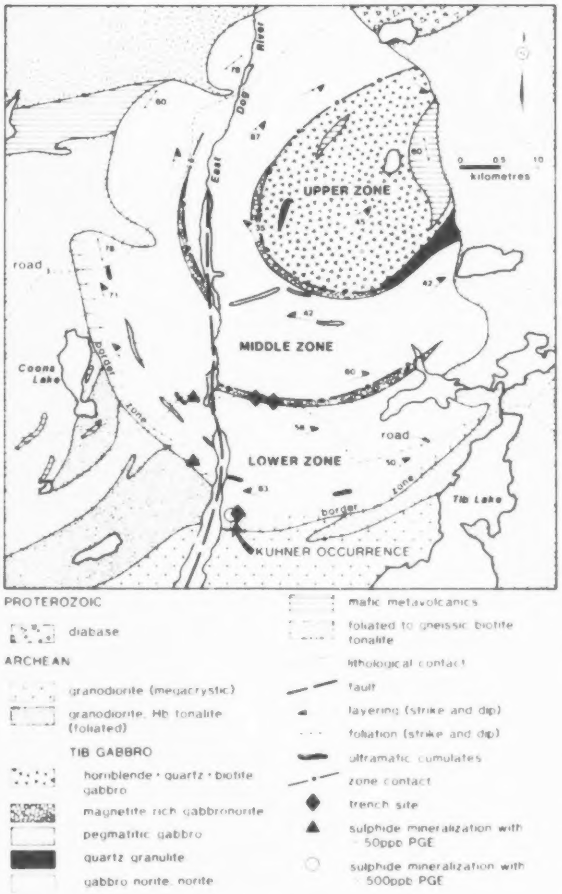
UPPER ZONE
MIDDLE ZONE
LOWER ZONE
KUHNER OCCURRENCE
East Dog River
road
road
Coons Lake
Tib Lake
border zone
border zone
kilometres
PROTEROZOIC
diabase
ARCHEAN
granodiorite (megacrystic)
granodiorite, Hb tonalite (foliated)
TIB GABBRO
hornblende + quartz + biotite gabbro
magnetite rich gabbronorite
pegmatitic gabbro
quartz granulite
gabbro norite, norite
mafic metavolcanics
foliated to gneissic biotite tonalite
lithological contact
fault
layering (strike and dip)
foliation (strike and dip)
ultramafic cumulates
zone contact
trench site
sulphide mineralization with 50ppb PGE
sulphide mineralization with 500ppb PGE

Figure 016.1. *Geological map of the Tib Gabbro.*

western, and southern margin of the intrusion. Coarse-grained to pegmatitic hornblende gabbro and gabbronorite are the predominant lithologies. Medium to coarse biotite and quartz and are rare to absent in rocks within the other zones. Concentrations of up to 1 percent sulphide mineralization (pyrrhotite, pyrite, and chalcopyrite) are common in the Border Zone.

Uniformly coarse-grained rocks along the outer edge of the Border Zone grade into medium-grained gabbro with pegmatitic patches and layers towards the inner parts of the zone.

The Lower Zone attains a maximum width of 1.5 km and has a maximum strike length of 7.4 km. This zone consists of a sequence of weakly layered gabbronorites and gabbros grading up into a well layered sequence with melagabbronorite and orthopyroxenite (pyroxene and cumulate) layers hosted in gabbronorite. Narrow conformable pegmatitic lenses and magnetite-rich zones of short (tens of metres) extent are found in close proximity to the ultramafic rocks. Orthopyroxenite layers are 2 to 3 m in width and are locally uralitized along fractures and in pegmatitic patches. Above the orthopyroxenite, a narrow horizon within medium- to coarse-grained massive gabbro contains small inclusions of finer grained gabbronorite. Some of the inclusions contain net-textured sulphide mineralization. The horizon represents a transition between massive gabbro and fine-grained layered gabbronorite, and may, on a basis of textural criteria, have been formed by magma mixing processes.

Above the orthopyroxenite, lithologies become more leucocratic, and anorthosites appear as distinct layers. Intermittent modal layering is well developed at this level. The top of the Lower Zone is marked by a magnetite-rich gabbronorite with leucocratic layers.

The 1.6 km wide Middle Zone is similar in width and overall strike length (approximately 7 km) to the Lower Zone. Gabbronorite is again the dominant rock type; however, leucocratic units are more abundant here than in the Lower Zone. Melanocratic and ultramafic cumulates occur as conformable horizons approximately 500 m above the base of the zone. These units, however, appear to pinch out along strike, and can only be traced for tens of metres. Middle Zone gabbroic rocks are hornblende-rich, particularily in the northwestern part of the intrusion. Conformable pegmatite layers are found within the upper part of the zone; however, discordant pegmatite dikes are more common. The top of the Middle Zone is marked by a well layered magnetite-rich gabbronorite.

The Upper Zone is irregular in shape with a circular basal portion 2 km in diameter and a stem protruding to the northeast for 800 m. The zone is characterized by hornblende-rich massive to weakly-layered gabbronorite. Layers form a concentric pattern with a shallow inward dip. A leucocratic quartz-bearing granulite unit forms a discontinuous outer rim of variable width around the Upper Zone. This unit is interpreted to be a metamorphosed tonalite, but alternatively may be a final product of fractionation.

Layering present in the Tib Gabbro is comparable to that developed in the Mulcahy Gabbro (Sutcliffe and Smith 1985). Planar lamination of feldspars and pyroxenes is found throughout the intrusion. Modal layering, defined by changing concentrations of cumulate phases, is best developed in the upper part of the Lower Zone. Modal layering occurs both in intermittent and cyclic layer sequences. Distinct modal layers include orthopyroxenite (orthopyroxene cumulate), websterite (orthopyroxene-clinopyroxene cumulate), anorthosite (plagioclase cumulate), and magnetite cumulate. Ultramafic cumulates occur most frequently in the Lower Zone. Modal layers are tens of centimetres in width, and persist for tens of metres along strike.

Mineralogically graded layers, defined by grading of pyroxene versus plagioclase, are common in the upper part of the Lower Zone. Structures indicating facing direction are rare, but consistently indicate stratigraphic tops toward the interior of the intrusion. Average compositions of the mineralogically graded layers are similar to the uniform gabbronorite phase.

Wispy or irregular layering, characterized by lensoid concentrations of pyroxene or feldspar in a gabbronorite host, is common throughout the intrusion. Layers are locally contorted into tight folds, which may be a result of slumping processes prior to solidification of the magma.

Pegmatoid layers, present in the Border, Lower, and Middle Zones, are narrow (tens of centimetres) and of short strike length. Horizons containing these layers, however, can be locally traced for hundreds of metres. Pegmatoid rocks are typically altered hornblende gabbros which may contain quartz and biotite.

Granitoid rocks in the map area form two distinct suites. The Tib Gabbro has intruded an older suite of highly foliated to gneissic biotite tonalite, which outcrops around the eastern, northern, and northwestern margins of the intrusion. The contact between the Tib Gabbro and older tonalite is not observed in outcrop; however, dikes of gabbro were observed to discordantly intrude gneissic tonalite on the northern margin of the intrusion.

A younger suite of foliated hornblende tonalite and foliated to massive granodiorite postdate the Tib Gabbro. These lithologies also occur within the intrusion, typically forming narrow dikes and stringers near the margins, and narrow sills higher in the intrusion. The development of an intrusion breccia with gabbro fragments in a matrix of younger granitoid was observed at one locality.

The younger suite of granitoids borders the southern and southwestern edges of the intrusion, where contact relationships are complex. Proceeding along the intrusion boundary in a northwesterly direction, massive megacrystic granodiorite grades into foliated granodiorite and finally into a foliated hornblende tonalite. This wedge of younger granitoids appears to intrude older foliated to gneissic tonalite.

Mafic metavolcanics in the map area occur as narrow lenses and inclusions within foliated to gneissic biotite tonalite. Compositionally, these metavolcanics are typically fine-grained amphibolite to clinopyroxene amphibolite with steeply-dipping schistosity or gneissosity. Mafic flows with deformed relict pillows and calc-silicate pods were locally observed. Most of the metavolcanics are located in the northern part of the map area and are part of the Garden Lake supracrustal belt. Included blocks of fine-grained granulite facies mafic volcanic rocks occur within gabbronorites near the outer margin of the Tib Gabbro.

The youngest rocks in the map area consist of Keweenawan diabase sheets. These sheets are composed of fine- to medium-grained ophitic diabase, and intrude granitoid and mafic intrusive rocks at the extreme northern end of the area.

Radiometric ages have not yet been determined for the Tib Gabbro; however, field relationships indicate an Archean age. Zircon dating by D.W. Davis is currently in progress at the Royal Ontario Museum.

STRUCTURE AND ALTERATION

The presence of inward-facing modally-graded layers, which dip steeply inward at the intrusion margin and less steeply nearer the centre, suggests a funnel-shape for the Tib Gabbro. The presence of dish-shaped to arcuate zones, facing to the northeast, suggests that the intrusion has been tilted in this direction.

Most of the intrusion is characterized by primary igneous mineralogy; however, alteration of pyroxene to uralitic amphibole is locally present along fractures. Alteration is more pervasive in the Border Zone coarse-grained to pegmatitic gabbro.

Small scale faulting has produced offsets in layers, with maximum displacements of 1 to 2 m. Some layer offsets occur across narrow (10 to 30 cm wide) mafic dikes. These dikes range in composition from melagabbronorite to gabbronorite to gabbronorite to norite.

The only major deformational zone within the Tib Gabbro is an approximately north-striking fault located along the East Dog River. An apparent dextral displacement of 500 m is indicated by an offset of the southern contact of the intrusion. Small shear zones in close proximity to the fault contain narrow (0.1 to 0.5 m wide) quartz veins.

ECONOMIC GEOLOGY

A zone of sulphide mineralization with platinum group element values, known as the Kuhner Occurrence, is located within coarse-grained to pegmatitic rocks on the southwestern margin of the intrusion. The mineralization occurs in melagabbronorites to norites and consists of pyrrhotite, chacopyrite, and pyrite. The sulphide mineralization occurs as fine disseminated grains as rounded aggregates, up to 8 mm in diameter, and as intercumulus networks. One chip sample, taken by the field party across a 2.4 m interval (the length of the trench) returned values of 390 ppb Pd, 190 ppb pt, 120 ppb Au, 1140 ppm Ni, and over 10 ppm Cu (analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto).

Anomalous PGE values were obtained from a number of sulphide mineral-bearing layers discovered during the current mapping project. One layer, located stratigraphically above an orthopyroxene cumulate in the Lower Zone (see Figure 016.1), contains sulphide mineral-bearing inclusions in a zone of magma mixing and brecciation. Mineralization consists of disseminated to net-textured pyrrhotite, pyrite, and chalcopyrite, in a weakly magnetic gabbronorite. A grab sample taken by the field party containing 2 to 3 percent sulphide mineralization returned values of 115 ppb Pd, 59 ppb Pt, 40 ppb Au, 1330 ppm Ni, and 1840 ppm Cu (analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto).

Another sulphide mineral occurrence with anomalous PGE was sampled by the field party along the southwestern contact within the Border Zone. Altered, coarse-grained gabbro with less than 1 percent sulphide mineralization (pyrite, pyrrhotite, and chalcopyrite) gave values of 45 ppm Pd, 17 ppb Pt, 344 ppm Ni, and 108 ppm Cu (analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto).

Sulphide mineral-bearing zones, delineated during this mapping project, can be divided into four categories on the basis of rock type and structure. These zones represent favourable environments for PGE mineralization associated with magmatic sulphide mineralization or sulphide mineralization associated with late magmatic fluids. The host categories are:

1. massive coarse-grained to pegmatitic gabbros within the Border Zone of intrusion
2. inclusion-bearing layers formed by assimilation and/or magma mixing
3. conformable pegmatitic layers and stringers, and discordant pegmatite dikes
4. conformable melanocratic to ultramafic layers of orthopyroxenitic or websteritic composition.

The large fault zone in the western half of the intrusion is an exploration target for PGE and other precious metals, including gold and silver. This fault displaces border zone rocks, which contain anomalous PGE mineralization both east and west of the fault. The deformation zone may provide structural control for channeling mineralized fluids. Quartz veins located in shears associated with the fault may warrant examination for gold mineralization.

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017. Petrological and Economic Geological Studies on the Northern Lac des Iles Complex, District of Thunder Bay

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INTRODUCTION

A study of the northern ultramafic centre of the Lac des Iles Complex, an area covering 2.5 by 5 km, was carried out by E. Linhardt during the 1986 field season. This study concentrated on the detailed mapping of the igneous stratigraphy in the area with respect to the distribution of platinum group element (PGE)-bearing sulphide mineral occurrences. This report summarizes the result of investigations in 1986 and is the field basis for Linhardt's Ph.D. thesis at the University of Munich. The work is based on initial mapping by Pye (1968) and Sutcliffe and Sweeny (1986). For background information on mineral exploration, general geology, and economic geology, the reader is referred to Pye (1968) and Sutcliffe and Sweeny (1986).

GEOLOGY

The northern part of the Lac des Iles ultramafic intrusion (Figure 017.1) consists of dunite and wehrlite, olivine clinopyroxenite, clinopyroxenite, and websterite. Locally websterite grades into gabbronorite. Most of these lithologies occur in discontinuous units which range from several tens of metres to several hundreds of metres in width. The lack of traceable marker horizons and the discontinuous nature of units has made it difficult to interpret the igneous stratigraphy of the intrusion. Layering measurements and the geometry of websterite and clinopyroxenite units with distinct compositional and textural characteristics; however, suggest that the primary cumulates form dish-shaped layers. This geometry is supported by the occurrence of sulphide mineralization which appears to form stratiform layers in some websterite and gabbronorite horizons.

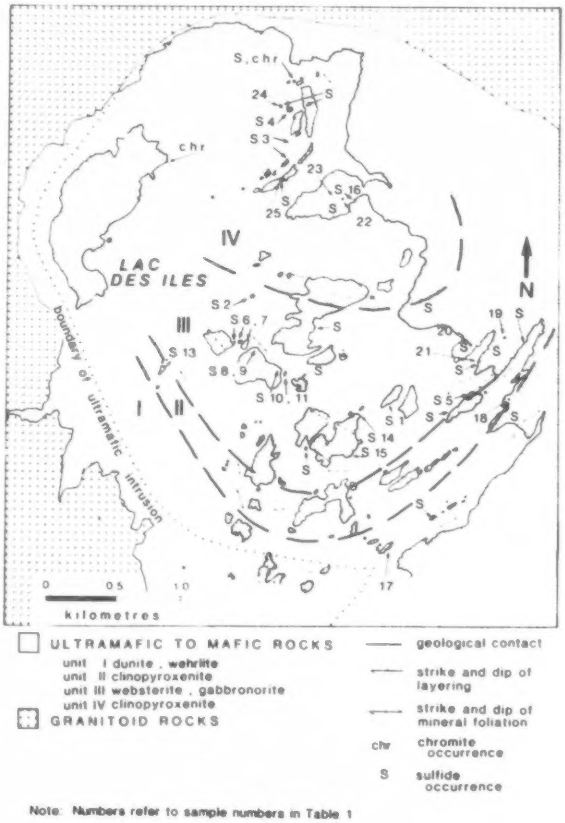
Using this geometry, several zones may be distinguished according to the predominant lithology. From the base of the sequence upwards, these zones are:

1. a lower zone characterized by the occurrence of serpentinized dunite and wehrlite
2. a zone containing dominantly olivine clinopyroxenite to clinopyroxenite
3. a zone consisting of dominantly websterite to gabbronorite
4. a second zone of clinopyroxenite.

This overall sequence is complicated by the occurrence of smaller lithologically distinct units within the major zones. These units indicate complex, small scale cyclic repetitions of lithologies within the zones. Furthermore, most of the mapped units show an irregular overprint of serpentinization which, in general, parallels the primary stratigraphy or follows fractures with 060° and 030° trends. Serpentinite dikes and serpentinite breccia zones with angular fragments of pyroxenite, are a discordant feature in the ultramafic rocks which may also be related to the introduction of serpentine.

In contrast to these processes in which serpentine has been introduced along fractures, serpentine is also recognized as an alteration of primary olivine in dunite and wehrlite. This type of serpentinization is recognized in the field by the presence of oikocrystic clinopyroxenes containing inclusions of relict olivine, now pseudomorphed by serpentine. The oikocrystic clinopyroxenes occur in conformable pegmatitic lenses or layers along the interface between dunite-wehrlite and clinopyroxenite.

Clinopyroxenite, which underlies almost 70 percent of the mapped area, forms massive units which locally exhibit igneous layering and lamination. These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24
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III
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S 13
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S 8, 9
S
S
boundary of ultramafic intrusion
S 10, 11
I
II
S 5
S 1
S
18
S
S 14
S 15
S
S
17
0
0.5
1.0
kilometres
ULTRAMAFIC TO MAFIC ROCKS
unit I dunite, wehrlite
unit II clinopyroxenite
unit III websterite, gabbronorite
unit IV clinopyroxenite
GRANITOID ROCKS
geological contact
strike and dip of layering
strike and dip of mineral foliation
chr chromite occurrence
S sulfide occurrence
Note: Numbers refer to sample numbers in Table 1

Figure 017.1. Geological diagram of the northern part of the Lac des Iles Complex.

TABLE 017.1: ASSAY SAMPLE ANALYSES, LAC DES ILES AREA.

Sample No.	Au(ppb)	Pt(ppb)	Pd(ppb)
1	14	32	100
2	50	97	360
3	115	210	95
4	105	140	85
5	15	29	95
6	14	37	125
7	6	14	65
8	10	35	15
9	50	67	125
10	16	28	90
11	6	25	35
13	9	34	335
14	2	11	28
15	13	56	145
16	295	680	910
17	10	19	65
18	220	350	2200
19	35	110	210
20	29	45	33
21	265	270	260
22	50	125	340
23	35	130	430
24	65	70	25
25	14	50	210

units are medium- to coarse-grained rocks with grey-green to emerald green colour. The texture of the clinopyroxenites is variable and there is a highly variable serpentine content.

Websterite shows greater uniformity than the clinopyroxenite. The typical websterite is medium grained with a homogenous texture and composition. Orthopyroxene tends to be finer grained than clinopyroxene and accounts for 10 to 25 percent of the rock. Serpentine is usually absent. Minor interstitial plagioclase is present, and, with increasing abundance, the websterite grades to gabbronorite. A less common variety of websterite contains up to 10 percent serpentine and may represent a transitional phase between clinopyroxenite and typical websterite.

The known sulphide mineralization mapped in the northern part of the Lac des Iles Complex are concentrated within the websterite and gabbronorite units. Chalcopyrite, which typically forms less than 1 percent of the rock in these occurrences, is the most abundant sulphide mineral. The chalcopyrite occurs as fine (0.5 mm diameter) disseminated grains and less common net-textured masses which are interstitial to silicate phases. Many of the sulphide mineralization occurrences display anomalous values for platinum group metals (PGE) (Table 017.1).

A significant new palladium-platinum occurrence was found in the southeastern part of the area. At this location, a grab sample (Sample 18, Table 017.1) of ultramafic rock with less than 1 percent chalcopyrite after analysis gave 220 ppb Au, 350 ppb Pt, 2200 ppb Pd, 174 ppm Cu, and 535 ppm Ni (analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto). This occurrence is in a well-layered sequence of websterite and clinopyroxenite, and represents a potential exploration target for stratiform PGE mineralization.

A new occurrence of chromite with 5 to 10 percent disseminated chromite in olivine clinopyroxenite, was found on the large island in the northwestern part of Lac des Iles (Figure 017.1).

SUMMARY

Summarizing these data, the following results can be stated:

1. The northern ultramafic centre of the Lac des Iles Complex is composed of a sequence of dish-shaped layers facing toward the northwest.
2. Four major zones, defined by the dominant lithology from the base of the sequence to the northwest are: dunite-wehrlite, clinopyroxenite, websterite, and clinopyroxenite.
3. Sulphide mineralization, with anomalous to significant PGE occurrences, predominantely occur in websterite and are a target for further exploration.

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1986: Precambrian Geology of the Lac des Iles Complex, District of Thunder Bay; Ontario Geological Survey, Map P.3047, Geological Series-Preliminary Map, scale 1:15 840 or 1 inch to 1/4 mile. Geology 1985.

018. Geology and Platinum Group Element Mineralization of the Roby Zone, Lac des Iles Complex

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INTRODUCTION

Investigation of the Boston Bay Mines Limited Roby Zone Deposit in the Lac des Iles Complex continued in 1986 with detailed mapping at a scale of 1:2400. This mapping will form the basis of petrologic and metallogenetic studies of this deposit which will be carried out by the first author and A.D. Edgar at the University of Western Ontario. The laboratory phase of this study is funded by the Ontario Geoscience Research Grant Program. The aim of the study is to investigate the relationships ships between gabbroic phases in the vicinity of the mineralized zone and the platinum group elements (PGE) mineralization.

The Boston Bay Mines Limited Property, in which Roby Zone is situated, is located immediately south of Lac des Iles. The property is accessible from Lac des Iles or by a road recently constructed by Boston Bay Mines Limited. This road links the property with Great Lakes Pulp and Paper Company logging roads in the Dog River area.

MINERAL EXPLORATION

Details of mineral exploration in the area prior to 1986 have been discussed by Sutcliffe and Sweeny (1986). During 1986, Boston Bay Mines Limited carried out a program of diamond drilling, trenching, and stripping on the Roby Zone. This work is part of a feasibility study toward the development of an open pit mine (The Northern Miner, Volume 72, April 7, p.1, 1986). The diamond drilling will test for extension of the mineralized zone at depth and toward the south.

To date, 20.4 tonnes of gabbro containing palladium (Pd) and platinum (Pt), with an average grade of 6.34 grams per tonne have been outlined in the deposit (Canadian Mines Handbook 1976-1977, p.314; The Northern Miner, Volume 62, October 21, p.27, 1976).

GEOLOGY

The Lac des Iles Complex was initially delineated by Pye (1968). Recently, Sutcliffe and Sweeny (1986) have mapped the complex at a scale of 1:15 840. Dunning (1979), Watkinson and Dunning (1979), and Talkington and Watkinson (1984) have reported the results of the investigation of the petrology and PGE mineralization of the Roby Zone, largely based on studies of diamond-drill core. This summary concentrates on field relations within the mineralized zones and the reader is referred to the papers cited above for details of mineralogy and PGE concentrations.

The Lac des Iles Complex consists of an ultramafic intrusion centred on Lac des Iles and a gabbroic intrusion south of the lake. The ultramafic and mafic rocks of the complex have not been significantly deformed or metamorphosed and intrude older gneissic tonalite. Younger granitic phases locally intrude the Complex. The PGE mineralization of the Roby Zone occurs in the gabbroic part of the Complex south of Lac des Iles.

Gunnex Limited in 1976 discovered eight zones of sulphide mineralization with PGE values, in the gabbro intrusion, which were named the "A" through "G" Zones. Subsequently in 1975 to 1976, Boston Bay Mines Limited and Texasgulf Canada Limited outlined a more extensive zone of mineralization, named the "Roby Zone" which encompassed the "E-Zone" of Gunnex Limited. The present exploration emphasis and the main aspect of this study is centered on the gabbroic rocks in the vicinity of the Roby Zone and the "C-Zone" to the south. These mineralized zones and the "B-", "F-", and "H-Zones" which occur in close proximity to the Roby Zone are illustrated in Figure 018.1.

Dunning (1979) subdivided the gabbroic portion of the Complex into an eastern gabbro and western gabbro, interpreted as separate intrusive phases. The contacts between these phases are fundamental in localizing the PGE mineralization. The eastern gabbro consists of medium-grained leucogabbro to gabbro with uralitic alteration of clinopyroxene. This phase is weakly layered due to the development of pyroxene-rich horizons, and locally has an igneous lamination. The pervasive alteration of pyroxene to uralite in the eastern gabbro suggests that the magma was volatile-rich.

The western gabbro consists predominantly of gabbronorite and typically has moderately to well preserved clinopyroxene and orthopyroxene. The two gabbro phases are also chemically distinct. The eastern gabbro has lower MgO, MgO/(MgO + FeO) and higher Al_2O_3 and CaO contents than the western gabbro. Dunning (1979) and Watkinson and Dunning (1979) believed that the western gabbro liquid contained the PGE, Cu, Ni, and S required to form the deposit.

A 60 to 300 m wide zone of magma mixing within the western gabbro adjacent to the eastern gabbro is the host for most of the PGE mineralization. This zone is heterogeneous but is typified by units of coarse-grained to pegmatitic gabbro and gabbro breccia.

Magma mixing in this zone is indicated by outcrop textures, mineralogy, and chemical character. These textures include: inclusions of leucogabbro with cuspate surfaces in gabbronorite; rounded, lobate interfaces between leucogabbro and gabbronorite; highly variable mineralogy and grain size on an outcrop scale; presence of numerous rounded inclusions with a variety of textures and mineralogies within the coarse-grained gabbro; and wispy to convoluted interlayering of melanocratic and leucocratic phases on a centimeter scale. On the basis of major

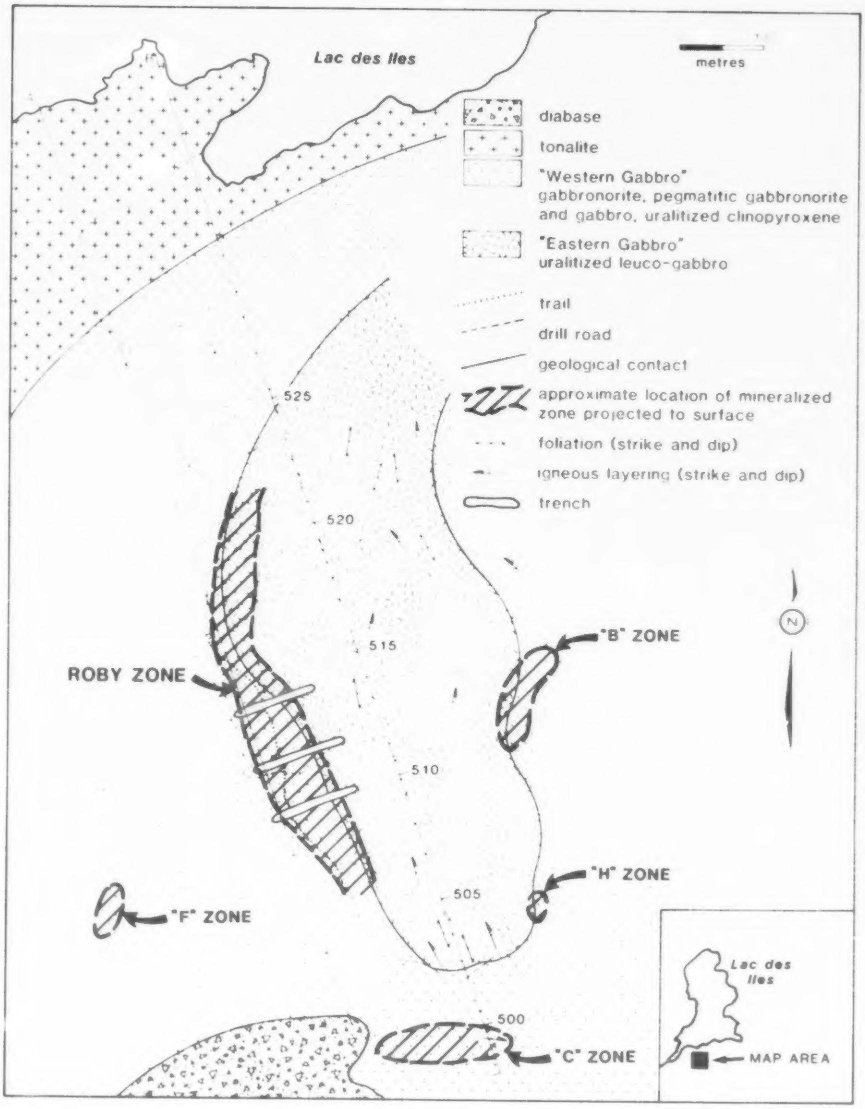
Lac des Iles
metres
diabase
tonalite
"Western Gabbro"
gabbronorite, pegmatitic gabbronorite and gabbro, uralitized clinopyroxene
"Eastern Gabbro"
uralitized leuco-gabbro
trail
drill road
geological contact
approximate location of mineralized zone projected to surface
foliation (strike and dip)
igneous layering (strike and dip)
trench
525
520
515
510
505
500
ROBY ZONE
"B" ZONE
"H" ZONE
"F" ZONE
"C" ZONE
N
Lac des Iles
MAP AREA

***Figure 018.1.** Geology and mineralized areas associated with the Roby Zone south of Lac des Iles.*

element geochemistry, the coarse-grained gabbro of the mixing zone falls into a compositional range between those of the eastern and western gabbros.

As originally reported by Dunning (1979) and Watkinson and Dunning (1979), the PGE mineralization of the Roby Zone occurs in association with sulphides along the eastern gabbro-western gabbro contact. The sulphides consist of up to 5 percent chalcopyrite, pyrrhotite, and pyrite, contained within the western gabbro. The sulphides occur predominantly as intercumulus blebs in a coarse-grained to pegmatitic gabbro phase of the magma mixing zone.

The coarse-grained gabbro phase is generally conformable to layering in the eastern gabbro, but locally, the mineralized coarse-grained to pegmatitic gabbro occurs as a discordant phase intrusive into medium-grained gabbro. Within the mineralized zone, diamond-drill core indicates that the coarse-grained gabbro is associated with interlayered medium-grained gabbronorite and altered pyroxenite (which is termed amphibolite in drill logs). The gabbronorite is mineralized, but in other respects is similar to the uniform western gabbro outside the Roby Zone. The altered pyroxenite unit is significant in that results of drilling by Texasgulf Canada Limited and Boston Bay Mines Limited indicate that it locally contains total PGE concentrations up to approximately 16 grams per tonne associated with minor amounts (typically 1 percent) of sulphide. The altered pyroxenite is commonly present as a unit several metres thick at the interface between the western gabbro and eastern gabbro as in Section 515. The altered pyroxenite is not well exposed in outcrop, but is locally observed to discordantly intrude the eastern gabbro.

The mineralization of the Roby Zone forms a stratiform unit continuous along strike for approximately 600 m, and is approximately 30 to 100 m wide. The zone dips 70°E to vertical. PGE mineralization terminates abruptly at the contact between the western and eastern gabbros on the east side of the zone, but diminishes gradually to the west.

The "C-Zone" (Figure 018.1) appears to be a zone of mineralization which is distinct from the Roby Zone. This zone, which is approximately 150 m long and oriented in an east-west direction, occurs within the zone of magma mixing in the western gabbro, but is apparently south of the eastern gabbro-western gabbro contact. Details of outcrop relationships within the "C-Zone" have been described by Sutcliffe and Sweeny (1985, cf. Figure 3). The zone contains interlayered medium-grained gabbro and gabbronorite with net-textured to disseminated sulphide. These rocks are discordantly intruded and disrupted by mineralized breccia zones and associated mineralized pegmatitic gabbro dikes which are thought to represent conduits along which mineralized, volatile-rich fluids were channeled. Inclusions of fine- to medium-grained mafic granulite are present in the vicinity of the "C-Zone" and may be of metavolcanic origin.

Current mapping (Figure 018.1) indicates that a unit of gabbronorite similar to the western gabbro extends northeastward from the "C-Zone" to the "B-Zone". This unit truncates layering and foliation in the eastern gabbro and suggests that the western gabbro was emplaced after the eastern gabbro. This interpretation suggests that "H-" and "B-Zones" also occur near the contact between the eastern gabbro and gabbronorite of the western gabbro. This contact area warrants further investigation for continuity of mineralization.

SUMMARY

Mapping during 1986 suggests that sulphides with PGE mineralization in the Roby Zone and adjacent "B-", "C-", "F-" and "H-Zones" are related to mixing between the gabbronoritic western gabbro and altered gabbro of the eastern gabbro. The mineralization is also closely associated with development of coarse-grained to pegmatitic gabbroic phases, gabbro breccia zones, and intrusion of pyroxenite.

The field studies combined with previous investigations suggest that the sequence of events leading to the development of mineralized zones involves: 1) intrusion of volatile-rich eastern gabbro; 2) emplacement of western gabbro containing PGE and sulphur into the eastern gabbro, resulting in magma mixing and the segregation of a magmatic sulphide phase; 3) fluxing of volatiles from the volatile-rich eastern gabbro into the mixing zone of the western gabbro, resulting in development of coarse pegmatitic phases and breccia zones; 4) redistribution of earlier formed magmatic sulphides in the gabbronorite by the volatile-rich pegmatitic phases. The mineralized altered pyroxenite may represent a pyroxene cumulate phase which was intruded prior to the main phase of western gabbro.

Studies of the Roby Zone at Lac des Iles emphasize the importance of recognizing mixing processes and volatile activity as a key to discovering other PGE occurrences.

ACKNOWLEDGMENTS

The authors would like to thank the staff of Boston Bay Mines Limited, particularly W. Matthews, for discussions on the geology of the Roby Zone during the field season.

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019. Blackwell and Laurie Townships, District of Thunder Bay

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INTRODUCTION

The map area comprises the Townships of Blackwell and Laurie and the extreme western end of the Dawson Road lots. It is bounded by Latitudes 48°30'00"N and 48°40'15"N and Longitudes 89°54'00"W and 90°01'30"W, and is centred about 58 km northwest of Thunder Bay.

Land access to the area is provided by Highways 11 and 17 immediately east of Blackwell Township and a forest access road which leads southward from Shabaqua Corners (immediately east of the map area) and traverses the southeastern part of the map area. Lumber roads of the Great Lakes Paper Company Limited, which begin at Highway 590 southeast of the map area, provide access to the area east of Gold Creek in southwestern Laurie Township. The Matawin River provides access to the south central part of the map area. The northwestern part of Laurie Township, and the southwestern and north central parts of Blackwell Township are best reached by helicopter.

An area of 161 km^2 was mapped during the summer.

MINERAL EXPLORATION

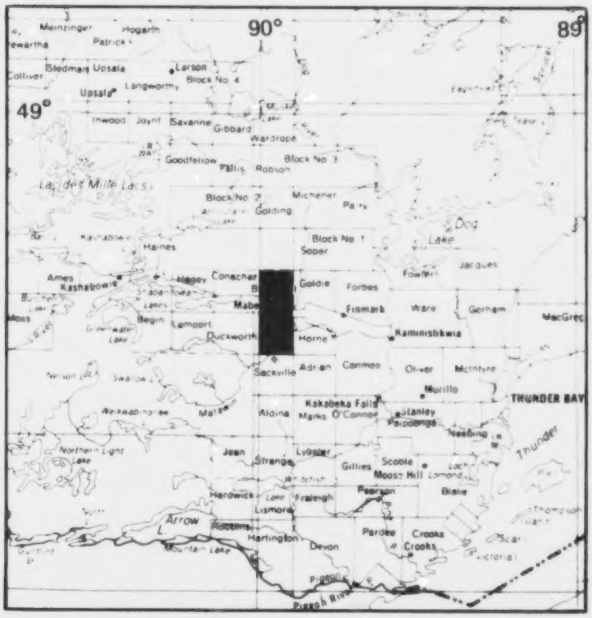
Unless otherwise stated, the following account has been summarized from the files of the Resident Geologist, Ontario Ministry of Northern Development and Mines, Thunder Bay, and the Assessment Files Research Office, Ontario Geological Survey, Toronto.

Exploration activity was carried out mainly for iron ore deposits in the 1890s and 1900s as the southern part of the map area lies astride the Matawin Iron Range. Exploration for gold, base-metal sulphide mineralization, and nickel became important in the second quarter of the present century. Recently, with favourable gold prices, considerable gold exploration has occurred in the south-central part of Laurie Township. Overall, most of the exploration activity has taken place in southern Blackwell Township and in Laurie Township, areas underlain by metavolcanics.

BASE-METAL SULPHIDE MINERALIZATION

In 1956, Three Brothers Exploration carried out a drill program along the northern shore of the Shebandowan River between Mabella and the confluence of the Oskondaga and Shebandowan Rivers. Five diamond-drill holes were put down totaling 3595 feet (1096 m).

At various times between 1967 and 1979, Noranda Exploration Company Limited carried out a series of ground electromagnetic and magnetic surveys in parts of southwestern and west central Laurie Township. One of the many conductors found was intersected by a diamond-drill hole 216.7 feet (66.1 m) long in 1967.


90°
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49°
Meinzinger
Hogarth
Patrick
Stedman
Upsala
Larson
Block No. 4
Langworthy
Inwood
Joynt
Savanne
Gibbard
Wardrope
Goodfellow
Fallis
Robson
Block No. 3
Lac des Mille Lacs
Block No. 2
Michener
Golding
Haines
Block No. 1
Soper
Dog Lake
Jacques
Ames
Kashabowie
Conacher
Goldie
Forbes
Fowler
Mabe
Begin
Lamport
Duckworth
Fraleck
Ware
Gorham
Horne
Kaministikwia
MacGregor
Sackville
Adrian
Conmee
Oliver
McIntyre
Murillo
THUNDER BAY
Aldina
Kakabeka Falls
Marks
O'Connor
Stanley
Paipoonge
Neebing
Thunder
Jean
Strange
Lybster
Gillies
Scoble
Moose Hill
Lochlomond
Northern Light Lake
Hardwick
Pearson
Blake
Lismore
Arrow
Robbins
Hartington
Devon
Pardee
Crooks
Mountain Lake
Pigeon River

LOCATION MAP

Scale : 1 : 1 584 000
or 1 inch to 25 miles

In the period March 1972 to March 1973, J.C. Byrne (Caltor Syndicate) drilled nine diamond-drill holes for a total length of 3371 feet (1027 m) in south central Laurie Township.

GOLD

In 1937, Hialeah Gold and Metals Limited conducted a program of stripping and trenching in an area about 2.4 km from Shabaqua Station in northwestern Laurie Township. This work was prompted by the discovery of free gold in blue quartz veins occurring in oxidized schist, rhyolite, and feldspar porphyry.

In 1945, gold was discovered at the Kaspar Occurrence in southwestern Blackwell Township. Trenches and pits were excavated and examined by Sylvanite Gold Mines Limited and M.W. Bartley. In 1976, Noranda Exploration Company Limited carried out geophysical, geochemical, and geological surveys in an area which included this occurrence. Numerous conductive zones and magnetic anomalies were detected. The geochemical survey, which was carried out in soils overlying several airborne conductors, indicated several copper anomalies and two zinc anomalies. Subsequently, in 1982, Lacana Mining Corporation carried out a geological and geophysical survey on a property which also included the Kaspar Occurrence. The geophysical work indicated that the property was underlain by numerous conductive zones indicative of graphitic interflow sedimentary rocks.

In 1958, George Chilian drilled ten diamond-drill holes for a total of 564 feet (172 m) and dug four trenches in northwestern Laurie Township.

In 1983, Corporate Oil and Gas Limited carried out geological and geochemical surveys on two claim groups, one in southeastern Blackwell Township and the other in northeastern Laurie Township. This geochemical survey detected gold anomalies in three soil horizons in both claim groups.

From January to March 1985, Jalna Resources Limited had airborne magnetic and electromagnetic geophysical surveys flown over an area which straddled the Duckworth-Laurie Township boundary and covered part of southwestern Laurie Township.

During the current survey, two pits were found on the Edwin Kukkee Property located at Middle Falls, Matawin River. Grab samples from mineralized quartz-carbonate veins in the pits were previously taken for assay. The results are reported in the "Economic Geology" section.

IRON

In 1952, M.W. Bartley carried out a geological survey of a claim group located partly in east central Laurie Township, to evaluate the ore potential of local ironstone units of the Matawin Iron Range. Metallurgical tests were carried out which confirmed the unfavourable physical characteristics of the ironstone. The grade was also found to be inadequate for concentrating ore.

This investigation was followed in 1957 by a geological mapping program on the same iron range in the central part of that township by Monpre Mining Company Limited. The aim of that survey was to search for structural concentrations of the ironstone.

In 1956 and 1957, Bartley, Greer and Associates supervised a program of diamond drilling in which 19 diamond-drill holes were drilled in the ironstones in Laurie Township for a total of 10 592 feet (3228 m). Metallurgical tests were carried out in 1957 by H.U. Ross. The drilling indicated that about 100 000 000 tons of material was available in Laurie and Duckworth Townships. This deposit had an average iron content of 29.1 percent iron recoverable by open-pit mining with a waste to ore ratio of 1.07 to 1. In late 1967, a 250-pound (113 kg) sample was sent for metallurgical testing by Monpre Iron Mines Limited. Tests done in 1968 indicated that a marketable product of 68 percent soluble iron could be obtained from the raw material.

NICKEL

In 1962, Falconbridge Nickel Mines Limited diamond drilled one 651-foot (198 m) hole in southeastern Blackwell Township presumably in a search for nickel mineralization.

In the Summers of 1966 and 1969, The International Nickel Company of Canada Limited drilled a total of six diamond-drill holes for a combined length of 3899 feet (1188 m) in southwestern Blackwell Township, south of the Shebandowan River. Anomalies interpreted to be caused by ironstone or peridotite were found. These were checked by electromagnetic methods and four conductive zones were drilled. In the Fall of 1969, the same company drilled an additional four holes totalling 2043 feet (623 m) in the same area.

GENERAL GEOLOGY

The map area straddles the Abitibi-(Shebandowan Belt Section) Quetico subprovincial boundary and is underlain by Archean rocks (Figure 019.1) mantled by Pleistocene and Recent deposits. The southeastern part of the area had previously been mapped by Tanton (1925), and both townships had been mapped by Fenwick and Weinstock (1973).

The Archean rocks comprise Keewatin-type metavolcanics consisting of: komatiitic, tholeiitic and calc-alkalic units with interlayered Keewatin-type metasediments; Quetico-type clastic metasediments with minor interlayered metavolcanic rocks; intrusive ultramafic, mafic, and felsic rocks; Timiskaming-type metasediments with interlayered calc-alkalic and shoshonitic rocks; and diabase and lamprophyre dikes.

The Keewatin-type rocks underlie Laurie Township and the southern part of Blackwell Township, south of Highway 11. The Keewatin-type units consist of an older, tightly folded, steeply dipping sequence of subaqueous ultramafic to intermediate metavolcanics and metasediments which flank, on the north and south, a younger Keewatin-type subaerial intermediate to felsic metavolcanic and metasedimetary sequence which forms a linear, east-trending belt across south-central Laurie Township.

The older Keewatin metavolcanic sequence consists of interlayered units of komatiitic, tholeiitic, and

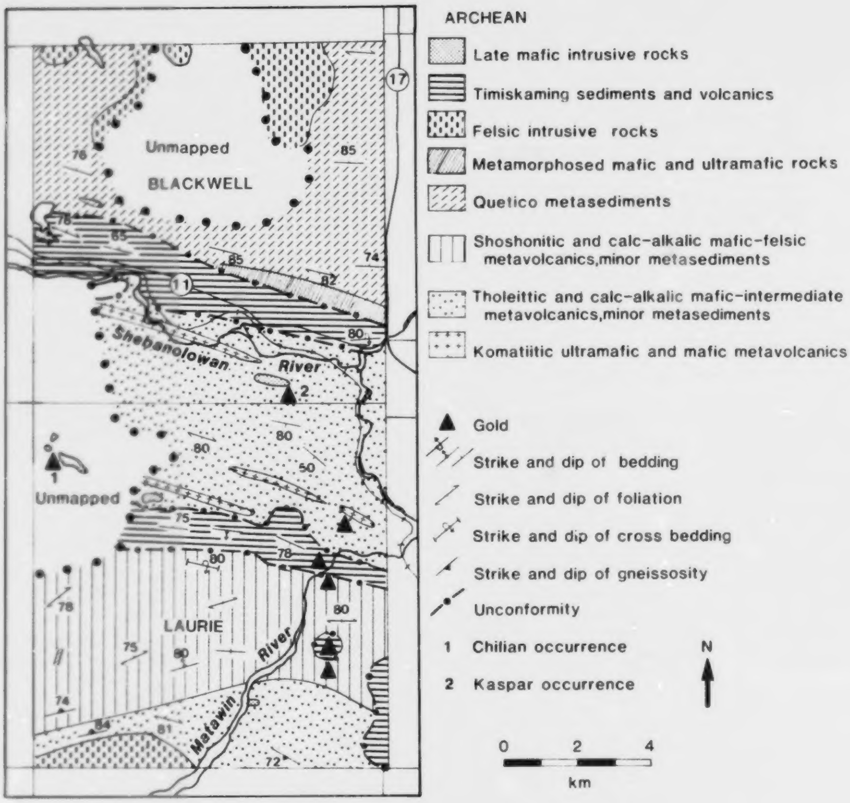
ARCHEAN
Late mafic intrusive rocks
Timiskaming sediments and volcanics
Felsic intrusive rocks
Metamorphosed mafic and ultramafic rocks
Quetico metasediments
Shoshonitic and calc-alkalic mafic-felsic metavolcanics,minor metasediments
Tholeittic and calc-alkalic mafic-intermediate metavolcanics,minor metasediments
Komatiitic ultramafic and mafic metavolcanics
Gold
Strike and dip of bedding
Strike and dip of foliation
Strike and dip of cross bedding
Strike and dip of gneissosity
Unconformity
1 Chilian occurrence
2 Kaspar occurrence
N
0 2 4
km
Unmapped
BLACKWELL
LAURIE
Shebandowan River
Matawin River
17
11
1
2
76
85
78
65
85
74
82
80
80
80
50
75
78
80
80
78
75
80
74
84
81
72

Figure 019.1. Geological sketch map of Blackwell and Laurie Townships.

calc-alkalic affinity. Ultramafic to mafic komatiites occur only on the northern flank of the younger Keewatin central edifice. These komatiitic rocks are characterized by spinifex textures, polygonal jointing, pillows, and varioles, and form sequences up to 170 m thick. Tholeiitic mafic to intermediate units with massive, pillowed, and amygdaloidal varieties occur on both the northern and southern flanks of the edifice in southern Blackwell and northern and southern Laurie Townships. On the northern flank, calc-alkalic rocks comprise feldspar-phyric basalts and aphyric andesitic and dacitic flows and tuffs, but these are absent on the southern side of the edifice.

The central part of the volcanic edifice, located in the south central part of Laurie Township, consists of a younger Keewatin sequence of hornblende-rich, probably high-potassium, calc-alkalic to shoshonitic intermediate and felsic rocks interlayered with mafic to intermediate metavolcanics. This area is dominated by coarse pyroclastic rocks consisting of tuffs, lapilli-tuffs, and tuff-breccias and is interpreted by the author as a central-facies volcanic unit (Williams and McBirney 1979, p.312-313; Easton and Johns 1986). These rocks have been the subject of a detailed study by Chorlton (in preparation).

The Keewatin-type metasediments, which are interlayered with the older metavolcanics, consist of clastic and chemical units. The clastic metasediments comprise conglomerate, wacke, argillite, and graphitic siltstones and mudstones which form sequences up to 100 m thick. On the southern flank of the volcanic edifice, in southern Laurie Township, a highly pyritic mudstone unit occurs which contains fine-grained disseminated pyrite forming up to 15 percent of the rock; this unit constitutes a marker horizon overlying the lower tholeiitic metavolcanics. The chemical metasediments comprise grey and black chert, silicified graphitic units, and banded magnetite-jasper ironstone. These chemical metasediments form units up to 30 m in thickness.

The Quetico-type metasediments occur in northern Blackwell Township and appear to be penecontemporaneous with the older Keewatin-type rocks as the two are interlayered in their mutual contact zone. These metasediments consist predominantly of wacke which are locally biotite-rich, siltstone, mudstone, siltstone-mudstone couplets showing grading bedding, and garnetiferous wacke. As these rocks are traced northward into northern Blackwell Township they become more highly metamorphosed, lose their primary characteristics, and are converted into paragneisses and migmatites. Locally, the rocks become coarser grained and form grey, biotite-rich, granoblastic tonalitic masses.

Mafic and minor ultramafic intrusions cut the Keewatin-type and Quetico-type rocks. These are lenses of dark green, coarse-grained gabbro and dunite-serpentinite. The gabbroic rocks in the northern part of the map area occur at the contact of the Keewatin-type and Quetico-type sequences.

Felsic intrusive rocks occur in the northern and southern extremities of the map area. These rocks are massive, biotite and hornblende-biotite granite, granodiorite, and tonalite with colour indices varying from 7 to 2. These rocks intrude the Quetico-type sedimentary rocks in the north and the tholeiitic Keewatin-type rocks in the south. Their relationship to the mafic intrusive gabbroic rocks is not directly observable.

Timiskaming-type metasediments occur in the southern part of Blackwell Township, straddling Highway 11, and in the north-central part of Laurie Township. These metasediments consist of oligomictic conglomerates and paraconglomerates containing clasts of predominantly intermediate, hornblende-bearing, calc-alkalic, and shoshonitic rocks, less common granitoid rocks, black chert, and jasper in an arkosic or chloritic matrix. Siltstone, mudstones, and arkoses also occur. Chemical metasediments comprise banded magnetite-jasper, magnetite-arkose and magnetite-mudstone units best exposed in the central part of Laurie Township where the unit is about 150 m thick. Timiskaming-type metavolcanics occur associated with the metasediments in the west-central part of Blackwell Township north and south of Highway 11. The rocks are characteristically hornblende-bearing and appear to be interlayered with the sedimentary rocks. They are similar to the rocks occurring in the central volcanic facies in south-central Laurie Township which suggests that late Keewatin-type volcanism continued into the period of Timiskaming deposition.

Late mafic intrusive rocks comprise fresh aphyric and feldspar-phyric north-trending and east-trending dikes, massive gabbroic rocks, diorite, and hornblende and pyroxene lamprophyre. Intrusive relationships with the Timiskaming-type rocks show that some of these lamprophyres represent the latest igneous activity in the map area. The diabase and lamprophyre dikes form bodies varying from 3 to 30 m in width.

Pleistocene deposits comprise: glaciolacustrine clays which are developed in northeastern and southeastern Blackwell Township and southeastern Laurie Township; ground moraine, that consists of sand and gravel, which occurs across the central part, and the northeastern corner of Blackwell Township; and Recent organic material comprising peat and muck along the upper reaches of the Matawin River in southern Laurie Township, along stream courses throughout Laurie Township, and in southern Blackwell Township (Mollard and Mollard 1980, 1981). An esker, consisting of cobbles and coarse sand forms a steep ridge which trends northeastward in southeastern Laurie Township (Mollard and Mollard 1981).

STRUCTURAL GEOLOGY

Structurally the area is characterized by an east-southeasterly grain which reflects the trends of folding and foliation within the Keewatin-type and Timiskaming-type rocks.

Folding in the older Keewatin-type metavolcanics and metasediments is tightly isoclinal about east-southeasterly axes in the northeastern part of Laurie Township and in the southeastern part of Blackwell Township. This trend veers to an east-west direction towards the west. Because of the severe deformation of primary features in the younger Keewatin-type volcanic rocks in south-central Laurie Township major structural patterns in that area are not known. Folding in the Quetico- and Timiskaming-type metasediments is also tightly isoclinal about east-southeasterly axes.

Foliation is well developed in the Keewatin-type and Timiskaming-type rocks. In the Keewatin-type rocks the foliation trends east-southeasterly with near vertical dips on the northern flank of the volcanic edifice. In southern Laurie Township, however, the foliation trend of the rocks on the southern flank of the volcanic edifice is arcuate, convex to the north. The author believes that this pattern is related to deformation associated with intrusion of a batholith, the northern edge of which is located in southwestern Laurie Township. Within the Keewatin-type rocks of the central facies, a northeasterly trend is dominant in the western part, and east-west foliations occur further east in the neighbourhood of the Matawin River. This pattern is also probably related to the batholith's intrusion.

Narrow shear zones varying from 1 to 10 m in width occur within the older Keewatin-type rocks, principally along the Shebandowan River south of Highway 11 and in the younger Keewatin-type volcanic sequence in southwestern Laurie Township. In the former area the shear zones trend easterly whereas in the latter they trend northeasterly.

A well developed mineral lineation is present in the rocks of the younger Keewatin-type metavolcanics in southwestern Laurie Township. The lineation is defined by acicular hornblende crystals, and plunges steeply to the northwest at 60° to 80°. This lineation is not as well developed in the eastern part of the edifice, but a single plunge measurement of 65° to the east-northeast was made in that area.

ECONOMIC GEOLOGY

GOLD

Kaspar Occurrence

Visible gold was reported from quartz veins in shattered diorite on this occurrence located in southeastern Blackwell Township by M.W. Bartley (Assessment File Research Office, Ontario Geological Survey, Toronto (AFRO)). In 1944 or 1945, J.A. McClosky of Sylvanite Gold Mines Limited carried out a program of channel sampling on the trenches of the property. He reported an assay of 0.52 ounce gold per ton over 3.7 feet (1 m) from sheared mineralized andesite (AFRO, Toronto).

Chilian Occurrence

This occurrence is located in northwestern Laurie Township in Keewatin-type metavolcanics. Sampling of an unknown kind by, George Chilian in 1958, returned a value of 9.45 ounces gold per ton (AFRO, Toronto) from a trench sunk on carbonatized andesite, containing mariposite alteration, a quartz vein, and a felsic dike.

Kukkee Occurrence

This occurrence is located on the Matawin River at Middle Falls, east-central Laurie Township in magnetite-arkose ironstone in the Timiskaming-type sequence. A grab sample from a quartz vein from one of the pits returned a value of 1.43 ounce gold per ton in 1984 (Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay).

During the current survey, grab samples were taken for gold determination from pyritized and/or gossanous rock and from quartz vein material in various parts of the township. Four of these samples returned values of 0.01 ounce gold or more per ton (analysis by the Geoscience Laboratories, Ontario Geological Survey, Toronto) viz:

1. 0.02 ounce gold per ton from a grab sample of sheared and silicified mafic volcanic rock containing pyrrhotite from Keewatin-type rocks in an outcrop located 0.9 km north-northeast of Lower Falls, Matawin River, in northeastern Laurie Township
2. 0.02 ounce gold per ton from a grab sample of carbonatized Timiskaming-type metasediment located 1.5 km south-southeast of McGraw Dam on the Matawin River in east-central Laurie Township
3. 0.01 ounce gold per ton from a grab sample of ankeritized Timiskaming-type conglomerate located 2 km south-southeast of McGraw Dam on the Matawin River in east-central Laurie Township
4. 0.01 ounce gold per ton from a grab sample of a pyritized quartz vein of unknown total width in Timiskaming arkose from Middle Falls on the Matawin River in east-central Laurie Township.

On the basis of these results, and previous extensive prospecting, it is suggested that shear zones located in the area between Highway 11 and the Shebandowan River, and on the river itself, be further prospected for their gold potential. The area at, and south-southeast of, Middle Falls in the Matawin River where carbonatized and sheared Timiskaming sediments and ironstone occur, and pyritized shear zones in the high-potassium calc-alkalic and shoshonite rocks in southwestern Laurie Township should also be further investigated.

IRON

Iron occurs as oxide-facies ironstone units interlayered with Keewatin-type metavolcanics and with Timiskaming-type clastic metasediments as at Middle Falls, Matawin River, in east-central Laurie Township. Although the iron is not of commercial significance at present, an ironstone unit at the Kaspar Occurrence was reported to be auriferous (AFRO, Toronto) where veined by quartz stringers are impregnated by pyrite and arsenopyrite. Similar indications were derived from the Kukkee Occurrence at Middle Falls, Matawin River, where it has been intruded by quartz and quartz-carbonate veins. It is suggested that ironstones be tested for their gold potential where cut by quartz or quartz-carbonate veins and/or mineralized with pyrite and arsenopyrite.

NICKEL

No assays for nickel have been recorded in the assessment files from areas of nickel mineralization in the map area. During the current mapping program units of ultramafic and mafic komatiites have been mapped in the southern part of Blackwell Township south of Highway 11, and in northern Laurie Township. These rock types are of significance in the search for nickel mineralization, and although no sulphide bodies were found on surface, it is suggested that these units be prospected for their nickel potential.

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Photo 021.2. *Folded metasiltstone, fine-grained metasandstone, and calc-silicate units. Partly transposed metasiltstone, upper left. Contorted calc-silicate beds, lower right. The hammer's length is 0.4 m. The view is to the north.*

zones, reveals very little definitive information regarding structural facing and fold closure. Preliminary evidence suggests that at least some of the turbidites lying between the main and lower mineralized zones may be overturned and on the northern limb of a west-closing fold.

Most dikes in the area are parallel or subparallel to bedding (except within the noses of isoclinal folds) and to the regional axial-planar cleavage. Some dikes can locally be seen to have intruded through fold hinges. This indicates, despite the diversity of the types of dikes (*see* section on "General Geology") that they intruded syn- or post-folding and are localized and/or controlled by the regional fabric.

LINEATIONS

Mineral lineations throughout the stratigraphic section to the west of the deposit (hanging wall and footwall) are consistently north-northwest-trending and moderately to steeply plunging. Stretch lineations are generally east or west trending and subhorizontal. In a few cases both lineations are present on the same surface suggesting formation at different stages, with later shearing tending to obliterate the mineral lineations. Locally, three and possibly four lineations (not of the slickenside variety) can be seen on a given face, considerably complicating their identification and interpretation.

SHEARING

Pervasive shear fabrics generally indicate dextral shear, supporting earlier observations of Hugon (1984), except around the ends of lithons (that is, small bodies of relatively undeformed rock surrounded by cleaved or sheared rock) where dextral and sinistral shear mechanisms have operated. Slickenside lineations within shear zones are either dextral or sinistral. In the case of the western end of the 'C' Zone mineralization (Page-Williams Mine Property), pervasive shear fabrics indicate dextral movement, whereas slickensides on fracture faces indicate a dominant sinistral sense of movement. Locally as many as three sets of slickenside lineations can be seen on a given surface.

FAULTING

Dislocation of units has occurred in at least five incompletely defined stages. The first stage resulted in the tight isoclinal folding in which volume accommodation within the hinge zone of the folds has led to transposition of bedding (ductile) and block faulting (brittle-ductile; Figures 021.1 to 021.4).

The second stage resulted in the major dextral shear event which involved ductile strike-slip displacements observed on outcrop scale (Figures 021.1 to 021.3). The effects of this dislocation probably resulted in much larger scale displacements but these are largely undefined at this time.

The third stage resulted in easterly trending, brittle-ductile, shallow angle to bedding strike, sinistral and dextral faulting which is common within 1 km of the deposit. Also common are dextral, shallow angle to bedding faults with accompanying drag folds. Detailed examples of the above faults are shown in Figures 021.1 to 021.4.

The fourth stage resulted in bedding planar breccias and pseudotachylite, through brittle mechanisms. This stage particularly affected rocks of relatively high competency, including parts of the mineralized quartz-feldspar-porphyritic complex, and in metasedimentary units as far as 2 km north of the deposit. The sense of movement on these faults is difficult to ascertain, but if they occurred during relaxation of the strain from ductile to brittle deformation then many or all may have a dextral sense. The breccias locally have disrupted, and therefore postdate, the drag folds. The resultant strike-slip displacements are of undefined magnitude.

The fifth stage resulted in relatively late, brittle, conjugate sets of fractures generally trending from

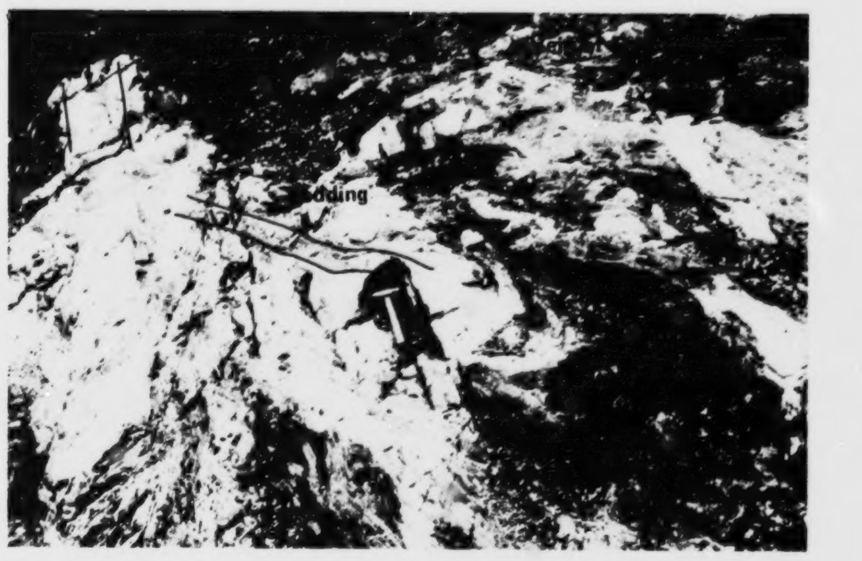

Photo 021.3. *Folded volcaniclastic metasediments, with later veins of feldspathization subparallel and parallel to axial planar cleavage, followed by intrusion of a feldspar porphyritic dike along the same cleavage set. The hammer's length is 0.4 m. The view is to the west.*

north-northwest to north-northeast, and was commonly accompanied by local bleaching of adjacent rocks.

ALTERATION

The author is not studying alteration types or patterns in detail. Nevertheless some general observations can be made.

Feldspathization, generally potassic, is one of the main types of alteration and is locally present in association with combinations of sericitization, biotitization, carbonatization, and tourmalinization.

The "main zone of feldspathization", which hosts the mineralization, has affected the quartz-feldspar-porphyritic complex, the structurally overlying and underlying epiclastic and volcaniclastic metasediments, and some dikes. The "main zone of feldspathization" is a term of convenience to connote the central area most strongly affected. There are variations of intensity and combinations of types of alteration within this "zone". Although the degree and pervasiveness of feldspathization wanes away from the deposit, some of the country rocks up to 300 m from the main zone of feldspathization have been affected.

Feldspathization or at least some of it, clearly post-dates the regional folding of the country rocks (Photo 021.3; Figures 021.1 and 021.3). Feldspathization forms two basic types of rocks within the quartz-feldspar-porphyritic complex:

1. thick units of lithologically massive, light to medium grey, fine-grained, microcline-rich quartz-eye-bearing rocks which are pervasively foliated but tend to have discrete, spaced shear planes
2. relatively thin, crudely tabular units of white, chalky weathering, very fine to fine grained, "icing-sugar"-textured rocks with very fine-grained pyrite and accompanying gold and molybdenum mineralization (Peter Cooper, Senior Geologist, Noranda Incorporated, Hemlo Division; Phill Walford, Chief Geologist, Lac Minerals Limited, Hemlo Division; personal communications, 1986):

The latter type of rock occurs along fractures and shears which appear to have controlled the passage of fluids and hence the distribution of this alteration. Generally, quartz phenocrysts have been destroyed in this type. The author is not yet certain of the relative timing or controlling factors responsible for these two apparently different types of alteration.

A notable amount of sericitization is present in parts of the main alteration zone, particularly at the eastern end of the deposit area, and in some of the units which structurally overlie and underlie the ore zone. It has affected, in particular, parts of the quartz-feldspar-porphyritic complex, and the adjacent metasediments. It appears to accompany transformation of biotite to sericite and, as well, the development of bright green micas. In many cases the green micas form lenses which the author interprets to be replaced fragments. The micas are vanadium rich (Harris 1986).

Biotitization of some rocks, within or on the margins of the main zone of feldspathization, has produced rocks with biotite-rich lenses and shear seams which together form crude anastomosing patterns. Other lenses, which are felsic to intermediate in composition, within these rocks show a diversity of textures and mineralogy. In some cases this heterogeneity likely reflects original fragments in altered pyroclastic and volcaniclastic rocks.

Tourmalinization has occurred in the stratigraphic section up to at least 2.5 km north of the deposit. It occurs in combinations of the following: a) on foliation planes; b) as veins with local bleaching of the country rock; c) with quartz veins; and d) as apparent selective replacement of some fragments in pyroclastic and volcaniclastic rocks. The tourmaline varies from:

1. well-oriented crystals parallel to regional mineral lineations (that is, north-northwest trending) in-

020. Barbara, Meader, and Pifher Townships, District of Thunder Bay

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Geologists, Precambrian Geology Section, Ontario Geological Survey, Toronto.

This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

LOCATION AND ACCESS

Barbara, Meader, and Pifher Townships are located on the eastern side of Lake Nipigon and are bounded by Latitudes 49°45'00"N and 49°50'30"N and by Longitudes 87°46'W and 88°09'W. They cover an area of 240 km^2. Beardmore, the nearest town, is 35 km by road from the southern boundary of Pifher Township. The city of Thunder Bay is located 190 km from Beardmore via Highway 11.

Pifher and Meader Townships are accessible by road. Highway 801 commences at Highway 11, 10 km west of Jellicoe and, provides access to the eastern part of Pifher Township. Alternate access is provided by a branch of Highway 580 linking Beardmore to the southern part of Pifher and Meader Townships. A gravel road connects these two routes in southern Pifher Township and continues into Meader Township. Several abandoned lumber roads provide good access to North Wind, Tyrol, Schroder, and Pifher Lakes. Barbara Township is most easily reached by boat from Lake Nipigon or by float-equipped aircraft.

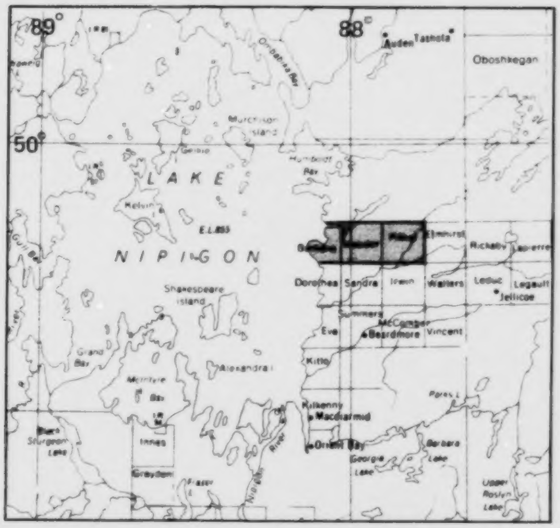
MINERAL EXPLORATION

Extensive mineral exploration in the area was initiated after the discovery of a gold-bearing quartz vein on the Maloney-Sturgeon Prospect in 1934 (Laird 1937). Since then, exploration activity has been sporadic in the area.

Newly discovered mineral occurrences within, and close to, the project area have prompted a staking rush within the past two years; many previously known deposits are being reinvestigated. Most of Pifher Township, the southern part of Meader Township, and the central part of Barbara Township are presently staked for a total of 803 claims.

The main target of the current exploration activity is gold. Northern Concentrators Limited of Thunder Bay has mined two high-grade, gold-bearing quartz veins on the Crooked Green Creek (CGC) Property since 1981. In 1985, approximately 200 tons of ore were milled from the CGC No. 2 zone (J.K. Mason, unpublished mineral commodity reports, Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay).

In 1982, 1224 tons of ore were mined by Thyssen Mining Construction (Canada) Limited for W. Miron on the Greenoaks Property, which straddles the Pifher-Elmhirst Township line (J.K. Mason, unpublished mineral commodity reports, Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay), and more ore was retrieved from the deposit during the Summer of 1986. Since 1984, an exploration program undertaken by Phoenix Gold Mines Limited, which included major overburden stripping and trenching operations, led to the discovery of several gold-bearing quartz veins in the vicinity of the Sturgeon River Gold Mine (V. Shein,


89°
88°
50°
Auden
Tashota
Oboshkegan
Ombabika Bay
Murchison Island
Geikie
Humboldt Bay
LAKE
NIPIGON
Kelvin
E.L.855
Gull B.
Shakespeare Island
Grand Bay
McIntyre Bay
Alexandra I.
Elmhirst
Rickaby
Laperrière
Dorothea
Sandra
Irwin
Walters
Leduc
Legault
Jellicoe
Summers
McComber
Beardmore
Vincent
Eve
Kitto
Kilkenny
Macdiarmid
Orient Bay
Georgia Lake
Barbara Lake
Poplar L.
Black Sturgeon Lake
Innes
Graydon
Fraser L.
Nipigon River
Upper Roslyn Lake

LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

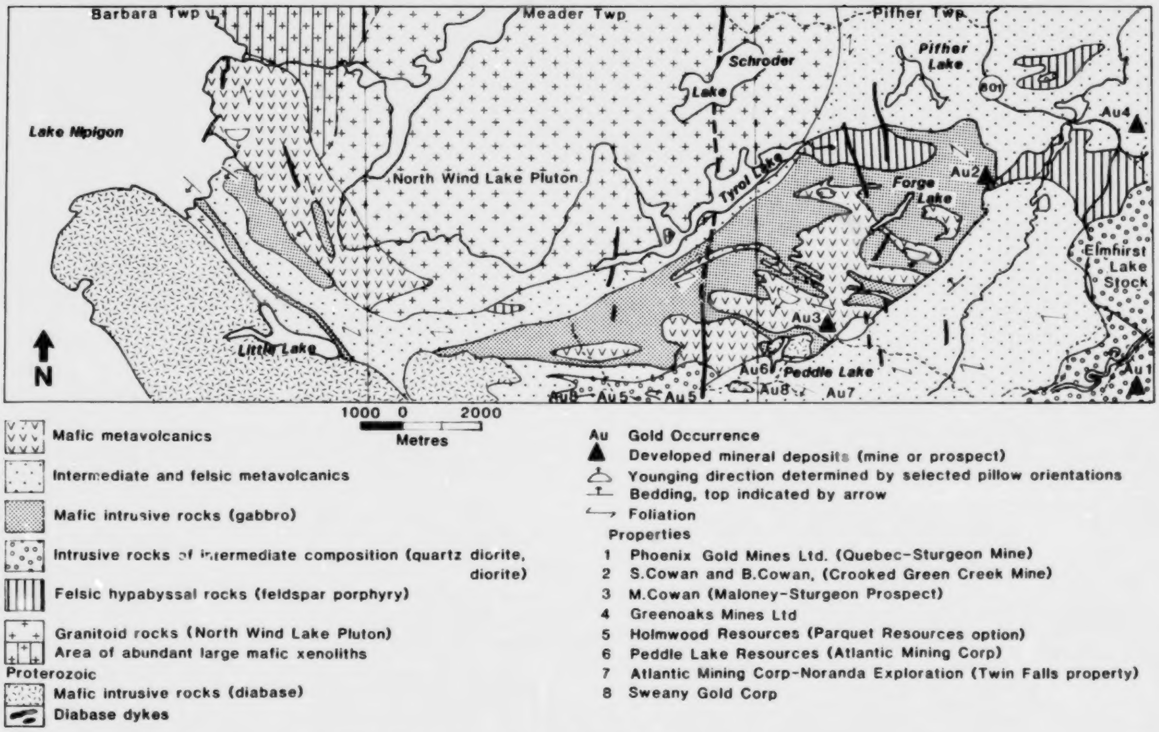

Barbara Twp
Meader Twp
Pifher Twp
Schroder Lake
Pifher Lake
801
Lake Nipigon
North Wind Lake Pluton
Tyrol Lake
Forge Lake
Au4
Au2
Au3
Elmhirst Lake Stock
Little Lake
Peddle Lake
Au6
Au8
Au7
Au5
Au5
Au1
N
1000 0 2000
Metres
Mafic metavolcanics
Intermediate and felsic metavolcanics
Mafic intrusive rocks (gabbro)
Intrusive rocks of intermediate composition (quartz diorite, diorite)
Felsic hypabyssal rocks (feldspar porphyry)
Granitoid rocks (North Wind Lake Pluton)
Area of abundant large mafic xenoliths
Proterozoic
Mafic intrusive rocks (diabase)
Diabase dykes
Au Gold Occurrence
Developed mineral deposits (mine or prospect)
Younging direction determined by selected pillow orientations
Bedding, top indicated by arrow
Foliation
Properties
1 Phoenix Gold Mines Ltd. (Quebec-Sturgeon Mine)
2 S.Cowan and B.Cowan, (Crooked Green Creek Mine)
3 M.Cowan (Maloney-Sturgeon Prospect)
4 Greenoaks Mines Ltd
5 Holmwood Resources (Parquet Resources option)
6 Peddle Lake Resources (Atlantic Mining Corp)
7 Atlantic Mining Corp-Noranda Exploration (Twin Falls property)
8 Sweany Gold Corp

Figure 020.1. *Geological map of Barbara, Meader, and Pifher Townships.*

geologist, Phoenix Gold Mines Limited, personal communication, 1986).

The Bruce Property in southern Meader Township, optioned to the Sweany Gold Corporation, is centred on a series of recently discovered chalcopyrite-gold-bearing quartz veins. Stripping and trenching on the occurrence, as well as in several other showings in Sandra Township, were in progress over the summer. To the east, on the Sandra-Meader Township line, the H. Holm Property, consisting of several copper-gold mineralized zones, has been sporadically investigated since 1935 for gold and base metal potential. The property is currently under investigation by Parquet Resources.

Peddle Lake Resources, an exploration arm of Atlantic Mining Corporation, undertook an extensive program of stripping, trenching, geological mapping, and diamond drilling at Peddle Lake, in the southwestern corner of Pifher Township, during the past summer. The work was carried out over an induced potential (IP) anomaly delineated by Lynx-Canada Explorations Limited in 1974 (A.D. Pudifin, consulting geologist, personal communication, 1986). The Sweany Gold Corporation Property consists of one claim adjoining the Peddle Lake Resources Property to the west. The property has recently been stripped and trenched and a diamond drilling program was begun late in the summer.

Intensive exploration work was done by Noranda Exploration Limited on the Twin Falls Property which straddles Pifher and Irwin Townships to the east. Recent activity on the property consisted of stripping, trenching, geological mapping, ground magnetometer, and IP surveys. Carling Gold Resources Incorporated conducted a diamond drilling program consisting of 13 holes in the southeastern corner of Pifher Township in 1984 and 1985. Hole CP-8 intersected a 6.1 foot section grading 0.37 ounce gold per ton (The Northern Miner, December 2, 1985).

GENERAL GEOLOGY

Barbara, Meader, and Pifher Townships (Figure 020.1) were originally mapped as part of a reconnaissance survey, extending from Lake Nipigon to Hipel and Colter Townships, by H.C. Laird (1937) and E.L. Bruce (1937). It was later investigated by W.O. Mackasey (1970a, 1971) as part of a multi-year mapping program in the Beardmore-Jellicoe area (Mackasey 1970c, 1970d, 1975, 1976a, 1976b; Mackasey *et al.* 1976a, 1976b; Mackasey and Wallace 1978).

The map area, situated in the central part of the eastern Wabigoon Subprovince, is part of the Beardmore-Geraldton metavolcanic-metasedimentary belt of Archean age (Mackasey 1970b). The northern part of this belt is dominated by a metavolcanic assemblage which is intruded by granitoid plutons (Pye *et al.* 1965; Stott 1984). These rocks are overlain by an extensive diabase sheet of Proterozoic age around Lake Nipigon.

The present project area lies entirely within the northern metavolcanic-plutonic domain mentioned above. Supracrustal rocks form a south-facing homoclinal sequence intruded to the north by a small granitic batholith, here called the North Wind Lake Pluton.

The metavolcanic rocks fall into two distinct composition classes. Felsic rocks of probable dacite composition underlie much of the area, forming an extensive zone 5 km wide by 25 km long from the northern part of Pifher Township in the east to Lake Nipigon in the west. In the southern part of Pifher Township, the felsic metavolcanics occur as monolithic pyroclastic deposits and flows representing a relatively proximal environment, while in the northern part of the township, the fragmental volcanic rocks appear to be heterolithic. To the west, in Meader and Barbara Township, the felsic units reflect a more distal depositional environment than in Pifher Township; they are characterized by well stratified tuffs, lapilli-tuffs, and tuff-breccias.

A large area in the west-central part of Pifher Township, and continuing into Meader Township, is underlain by basaltic rocks, massive and pillowed units intruded by medium-grained gabbro. The gabbroic intrusions are probably related to mafic volcanism and have previously been mapped by H.C. Laird (1937) as Keweenawan diabase and appear as such on existing compilation maps (Pye *et al.* 1965; Stott 1984).

Mafic volcanic rocks, in part consisting of amphibolite schists, are found north of the felsic volcanic rocks in Barbara Township and form a northwest-trending zone. Part of this sequence occurs as an area of large mafic xenoliths within the western part of the North Wind Lake Pluton.

Numerous felsic porphyritic dikes, small stocks, and sills related to felsic volcanism crosscut all volcanic lithologies. In southeastern Pifher Township, quartz diorite of the Elmhirst Stock, centred in Elmhirst Township to the east, (Mackasey and Wallace 1978) intrudes the felsic volcanic rocks. Several smaller quartz-diorite intrusions occur elsewhere in Pifher Township and the southern part of Meader Township. All Archean lithologies have been intersected by north-trending Proterozoic diabase dikes.

All Archean rocks within the map area have been subjected to low grade greenschist metamorphism. Rocks near the North Wind Lake intrusion have been upgraded to amphibolites; many of the felsic rocks in Meader and the northern part of Pifher Township have been strongly recrystallized. These rocks were previously reported as "hybrid rocks" (Laird 1937) and were mapped as part of the plutonic assemblage.

STRUCTURAL GEOLOGY

The Archean supracrustal assemblage within the map area consists of a south-facing homoclinal sequence according to younging indicators found within the volcanic rocks. Mackasey (1971) believed that the volcanic rocks in Pifher Township had been folded into an eastward plunging anticline with a core of mafic volcanic rocks and gabbro. The present survey could not confirm this interpretation due to the lack of structural data in the northern part of the township. Thinly bedded volcanic tuffs found in Pifher and Barbara Townships, with steep dips to the north, suggest an overturned sequence.

The volcanic assemblage is pervasively foliated in a northwest-southeast direction throughout the area. In the vicinity of the North Wind Lake Pluton, rocks are strongly foliated and the fabrics parallel the intrusive contact. Around Tyrol Lake, a strong, north-plunging, linear fabric is also present. A secondary crenulation cleavage intersects the primary foliation in several places in southern Pifher Township and in northern Barbara Township.

Despite the presence of a large number of topographic lineaments, few faults have been recognized. A major east-west structural break, the Paint Lake Fault, occurs 3 km to the south of the map area. The Musca Lake Fault, of lesser extent, is just outside of the southern limit of the map area. Small shears are common in the southern parts of Meader and Pifher Townships and are expressed as zones of intense schistosity that are commonly mineralized. These zones may be splays of the Musca Lake Fault or related to the forceful intrusion of small quartz diorite intrusions in the southern parts of Meader and Pifher Townships.

ECONOMIC GEOLOGY

GOLD

The surveyed area lies within the "Beardmore-Geraldton Gold Belt", once one of the major gold camps in the Canadian Shield. The first gold discovery within the area was on the Maloney-Sturgeon Property, Pifher Township, in 1934 (Laird 1937); in 1937, 73 ounces of gold and 16 ounces of silver (J.K. Mason, unpublished mineral commodity reports, Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay) were produced from a high-grade pocket within an up to 2 m wide, north-trending, steeply dipping quartz vein hosted in pillowed basalts. The find generated an immediate gold rush in the Sturgeon River area which led to the discovery of other gold showings (Laird 1937). One such discovery was the Sturgeon River Mine which produced 73 438 ounces of gold and 15 922 ounces of silver during the 1936 to 1942 period (J.K. Mason, unpublished mineral commodity reports, Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay). When the mine closed, 60 quartz veins were known on the property, many of which carried high gold grades but were narrow (Halladay 1985). Several more quartz veins, some of which are of considerable strike length, were discovered by Phoenix Gold Mines Limited during a recent exploration program. The deposit consists of an array of quartz veins in shear zones occurring within the margin of the Elmhirst Stock. The quartz veins, commonly boudinaged, carry free gold along with minor amounts of sulphide mineralization. The rocks in the vicinity of the quartz veins have been altered, and contain secondary silica, feldspar, chlorite, and tourmaline (Halladay 1985). The most spectacular alteration form is intense tourmaline replacement in the metavolcanics at the Irwin-Pifher Township line.

Two closely spaced occurrences, known as the H. Holm showings, occur just north of Musca and Pirum Lakes in southern Meader Township and have been investigated for their gold and base metal potential since 1935. Mineralization, found in west-trending shear zones up to 300 m long, cutting felsic metavolcanics adjacent to a small quartz diorite stock, and just to the north of the Musca Lake Fault, consists of chalcopyrite, pyrite, magnetite, and gold. One grab sample collected by the field party from a trench north of Musca Lake assayed 0.08 ounce gold per ton and 0.58 ounce silver per ton (Geoscience Laboratories, Ontario Geological Survey, Toronto). Several mineralized quartz veins in shear zones on the Sweany Gold Corporation (Bruce) Property occur along the western contact of the quartz diorite intrusion. Five grab samples, with sulphide mineralization, were taken by the field party from two trenches and assayed for gold and silver (Geoscience Laboratories, Ontario Geological Survey, Toronto). The results are as follows: 0.02, 0.02, 0.06, 0.39, 0.14, and 0.38 ounce gold per ton, and 0.1, 0.26, 0.58, 1.45, 0.26, and 0.38 ounce silver per ton respectively.

The Twin Falls Occurrences consist of several shear zones in highly foliated felsic pyroclastics in northwestern Irwin and southwestern Pifher Townships. Mineralization is present as pyrite and chalcopyrite in quartz veins or as massive pyrite bands or lenses occupying shear zones. Three grab samples by the field party from two different showings returned the following values: 0.32, 0.14 ounce gold per ton, and 681 ppb gold. Similar occurrences have been found on the Sweany Gold claim to the north. Anomalous gold values (Geoscience Laboratories, Ontario Geological Survey, Toronto) from 10 samples by the field party are as follows: 0.03, 0.06, 0.06, 0.14, and 0.22 ounce gold per ton; one sample with 0.01 ounce gold per ton assayed 3.82 ounces silver per ton. The Peddle Lake Occurrence, worked by Peddle Lake Resources, consists of numerous shear zones and quartz veins in highly foliated felsic volcanic rocks cut by several types of felsic dikes. From 26 samples collected by the field party and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, the highest values are 0.15, 0.04, and 0.03 ounce gold per ton, and 320, 280, and 190 ppb gold. Rocks within and near the shear zones are mildly carbonatized. On the southern end of Peddle Lake, the volcanic rocks are a peculiar green colour given by an as yet undetermined green mineral and contain a significant amount of a pink secondary mineral believed to be potassium feldspar.

Three major mineralized quartz veins containing chalcopyrite, pyrrhotite, and native gold occur on the Crooked Green Creek (CGC) Property on which gold was first found in 1946. The quartz is typically grey and appears to fill tension fractures in feldspar porphyry and at contact zones between gabbro and flow-banded dacite. Numerous gold assays ranging up to 20 ounce gold per ton have been reported from vein material (J.K. Mason, unpublished mineral commodity reports, Resident Geologist's Files, Thunder Bay).

A high-grade gold occurrence owned by Greenoaks Mines Limited, hosted in felsic metavolcanics which are intruded by dacite and rhyolite dikes, occurs about 2 km to the southeast of Miner Lake near the Pifher-Elmhirst Township line. Gold is concentrated in an east-trending grey quartz vein of variable thickness containing abundant chalcopyrite and pyrrhotite. A sample collected by the field party contained 11.07 ounces gold per ton and 4.29 ounces silver per ton (Assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto).

BASE METALS

Within the map area, copper mineralization has been found in quartz veins occupying shear zones and tension fractures; as lenses and bands with pyrite in shear zones; as disseminations in volcanic rocks in association with pyrite and pyrrhotite; and as joint filling minerals.

Mackasey (1970) reported a trench on the H. Holm Property at Pirum Lake that exposed a massive chalcopyrite-pyrite vein in foliated feldspar porphry. A channel sample by his field party was found to contain 16.8% Cu, 0.09 ounce Au per ton, 3.55 ounces Ag per ton, and traces of Co, Pb, Mo, Ni, and Zn (assays by the Geoscience Laboratories, Ontario Department of Mines, Toronto). A series of shears north of Musca Lake on the township boundary are also mineralized with chalcopyrite. Abundant patches of chalcopyrite and pyrite have been found by the field party in a quartz vein exposed in the trenches of the Sweany Gold (Bruce) Property to the west of the H. Holm showings. Chalcopyrite and pyrite occur in shear zones up to 1 m wide exposed in the recent trenches south of Peddle Lake. One such shear contained a pod of massive sphalerite. Chalcopyrite and pyrrhotite are common in the auriferous quartz veins on the CGC and the Greenoaks Properties.

Copper and zinc mineralization was found in felsic volcanic rocks as disseminated and small masses of chalcopyrite in the southeastern part of Pifher Township. A large number of northeast-trending V.L.F. electromagnetic conductors occur in that part of Pifher Township (Speed 1982). The best diamond-drill hole intersections, reported by Carling Copper Mines Limited from different sections, were 8.89% Cu over 1.0 foot, 16.17% Zn over 12.0 feet, 16.1% Zn, 0.18 ounce Au per ton, 0.08 ounce Ag per ton over 2.0 feet, and 6.29% Zn, 3.16 ounces Ag per ton over 7.0 feet (Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay).

A small sulphide mineral showing in quartz-carbonate stringers hosted in gabbro, known as the Coleman showing, occurs 1 km south of Tyrol Lake in Pifher Township. Reported mineralization includes pyrite, pyrrhotite, chalcopyrite, arsenopyrite, and some free gold. Copper and nickel values were reported (Resident Geologist's Files, Ministry of Northern Development and Mines, Thunder Bay). Only pyrite was found by the field party in one of the trenches.

Several zones, from 1 to 5 feet wide, in amphibolite schists, with disseminated pyrrhotite, pyrite, and chalcopyrite, were reported by W.O. Mackasey (1970) on the shorelines of Lake Nipigon, south of Vint Bay. Traces of Cu, Ni, Au, and Ag were found.

RECOMMENDATIONS FOR EXPLORATION

A spatial relationship between gold mineralization and quartz diorite intrusions in Pifher and Meader Townships has been established. Consequently, the marginal zones of these intrusions offer a highly favorable target for gold. A large area north of Peddle Lake in the west-central part of Pifher Township, underlain by mafic metavolcanics and gabbro intrusions, hosts numerous felsic dikes, shear zones, and quartz veins. That area was previously mapped as a Proterozoic diabase outlier, and may as a result have been neglected by explorationists in the past. The felsic rocks in Pifher Township offer an excellent environment for mineral deposits, particularly near felsic intrusive bodies and dikes which may host small-scale, high-grade gold deposits similar to the Crooked Green Creek and the Greenoaks gold deposits.

The contact zone between the mafic metavolcanic and the felsic metavolcanic assemblages in all three townships provides excellent potential for stratigraphically or structurally controlled gold and/or base metal deposits.

A series of electromagnetic conductive zones (Speed 1982) in southeastern Pifher Township merit further investigation for gold and base metals (copper-zinc).

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021. Hemlo Tectono-Stratigraphic Study

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INTRODUCTION

This study is a multiyear project intended to provide a detailed geological map and report on the Hemlo Deposit area; specific emphasis is placed on the identification of lithostratigraphic units and documentation of deformation events. The Hemlo Deposit is located about 35 km east of Marathon, Ontario. The limits of mapping are: Latitudes 48°40′30″N and 48°43′00″N, and Longitudes 85°51′30″W and 86°02′00″W. The area includes parts of Bomby and Lecoeur Townships. Over 20 mining claim groups lie wholly or partly within this 59 km^2 area.

Work during the field season included: detailed mapping of long, stripped trenches on the Golden Sceptre Resources Limited/Noranda Incorporated Property; stripping, hosing, and detailed mapping of selected outcrops on the Page-Williams Mine Property (The Page-Williams Mine ownership is currently the subject of litigation, and is operated under a joint operating agreement between Lac Minerals Limited and International Corona Resources Limited); continuation of a U-Pb geochronological study of the Hemlo-Heron Bay area in conjunction with Fernando Corfu (Royal Ontario Museum, Toronto); preliminary regional examinations with Greg Stott (Precambrian Geology Section, Ontario Geological Survey, Toronto) of the strain effects within major granitoid bodies and the adjacent and more distant supracrustal rocks; and visits and discussions with various mining and exploration industry personnel.

GENERAL GEOLOGY

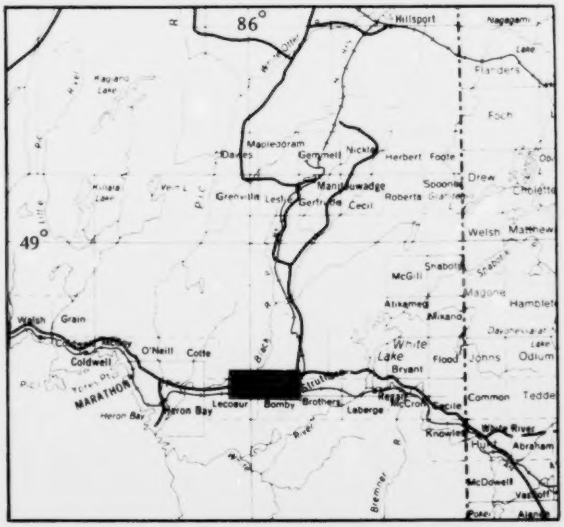
The general geology of the area has been described previously by Muir (1982, 1984, 1985a), Brown *et al.* (1985), Valliant *et al.* (1985), Quartermain (1985), Walford *et al.* (1986), and Patterson (1984, 1986), and will not be repeated here. Results of the author's last field season's work has been reported by Muir (1985b).

Particular attention was paid this year to the eastern half of the Golden Sceptre Resources Limited/Noranda Incorporated Property, where several stripped trenches up to 955 m long were made by Noranda Incorporated, and to the western part of the Page-Williams Mine Property where some trenching, stripping, and pitting of the 'C' Zone mineralization had been undertaken by Lac Minerals Limited. Both areas included the felsic to intermediate quartz-feldspar-porphyritic complex, which hosts the gold and molybdenum mineralization in that part of the Hemlo camp, and the structurally overlying and underlying units adjacent to it.

QUARTZ-FELDSPAR-PORPHYRITIC COMPLEX

The quartz-feldspar-porphyritic complex is likely part intrusive and part extrusive. The origin of much of the complex is equivocal due to the degree of shearing and/or alteration, and probably, in part, due to an original lack of distinctive features. Unequivocal intermediate to felsic, quartz- and plagioclase-phyric, subaqueously deposited pyroclastic rocks, ranging from heterolithic to monolithic varieties, are locally identifiable within and on the margins of the complex and form numerous units with maximum thicknesses on the order of 3 m.

Poorly defined felsic units are locally present in which there may be up to 15 percent heterolithic lapilli-size fragments in a feldspathized matrix. These units may be lapilli- and ash tuffs, or xenolithic intrusive bodies. Some of the fragments consist of varieties of porphyritic rocks unknown in dike form


86°
49°
Hillsport
Nagagami
Lake
Flanders
Foch
Kagiano Lake
Killala Lake
Maplejoram
Dayes
Gemmell
Nickle
Herbert
Foote
Drew
Manitouwadge
Spooner
Cholette
Grenville
Leslie
Gertrude
Cecil
Roberta
Welsh
Mathew
McGill
Shabotik
Magone
Atikameg
Mixano
Hamblet
Walsh
Grain
O'Neill
Cotte
Coldwell
MARATHON
Heron Bay
Lecoeur
Bomby
Brothers
Laberge
White Lake
Flood
Johns
Odlum
Bryant
Common
Tedder
McCron
Cecile
Knowles
White River
Abraham
McDowell
Bremner
Black
Pic
River

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

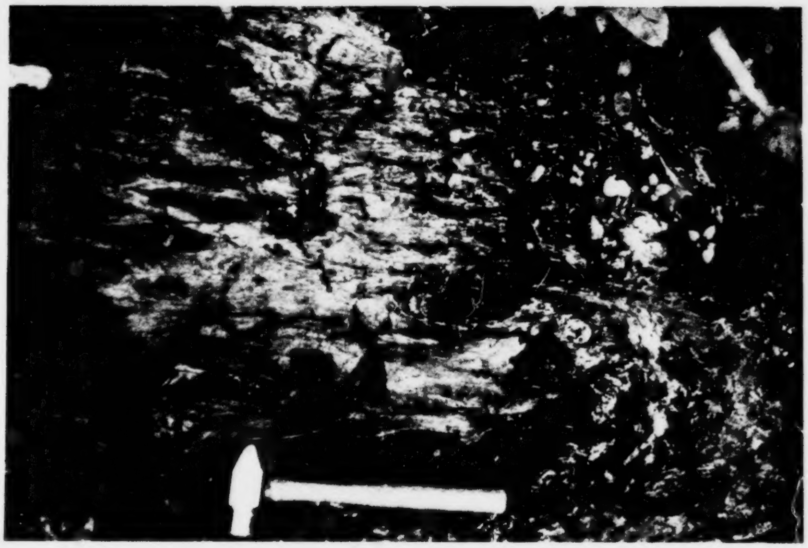


Photo 021.1. *Overturned, normally graded, heterolithic, lapilli-tuff. The hammer lies just inside the bottom contact of unit. The hammer's length is 0.4 m. The view is to the north.*

(numerous varieties of feldspar porphyritic dikes occur in the Hemlo area); they contain subhedral to euhedral feldspar phenocrysts in a dark aphanitic matrix, and appear analogous to some modern volcanic porphyries. Other fragments now consist largely of green mica. From these green mica fragments and similar examples noted elsewhere last year (Muir 1985b), it appears that many, but not necessarily all, green mica "lenses" were derived from altered lenses which were rich in biotite and/or sericite. Many of these were probably initially fragments, either pyroclasts or xenoliths.

Elsewhere, the quartz-feldspar-porphyritic rocks appear to be without xenoliths or fragments, and are lithologically "massive". These rocks occur mostly as two main types:

1. light to medium grey (fresh surface), feldspathized porphyry with discrete shears
2. highly feldspathized, white, "icing-sugar"-textured rocks

The latter type occurs as bodies with vein-like distribution controlled by zones of shearing, has pyrite and commonly associated gold and molybdenum mineralization on shear or fracture surfaces, and has few or no quartz phenocrysts. The latter appear to be partly or completely destroyed during feldspathization. In a few cases involving the light to medium grey variety, contact relationships with pyroclastic or sedimentary rocks are inferred to be intrusive.

VOLCANICLASTIC UNITS

Many examples can be found of volcaniclastic rocks with intermediate to felsic bulk composition, that is, rocks deposited by sedimentary processes but composed predominantly of volcanic detritus, likely derived from unconsolidated volcanic deposits. These rocks range from units derived largely from ash-size particles, to those containing numerous block-size clasts. In many cases a significant percentage of clasts are metasediments.

Significant apparent thicknesses of poorly bedded, felsic to intermediate units composed of ash- or sand-size particles are common. These units, likely formed from subaqueous deposits of ash, locally constitute major parts of the stratigraphic section in which few primary and structural features are sufficiently clear to determine younging directions or vergence.

Grading is present in a variety of size ranges in some pyroclastic and volcaniclastic units. It is locally still sufficiently distinct, despite strong flattening and/or some shearing, to determine younging directions, assuming normal grading is present (Photo 021.1; Figures 021.1 to 021.4). This information was coupled, where possible, with axial-planar cleavage/bedding relationships (*see* section on "Structural Geology").

EPICLASTIC UNITS

Units of wacke, feldspathic arenite, siltstone, and conglomerate, any of which (except conglomerate) may locally contain dark green amphibole-rich layers interpreted as calc-silicate beds, comprise the remainder of the stratigraphic section in this part of the area. Many units are clearly turbidite deposits, based on the vertical succession of primary structures; the dominant mechanism of deposition for the sediments, both epiclastic and, at least in some cases, volcaniclastic varieties, was of this nature. These rocks most readily developed axial-planar pressure solution cleavage (*see* Muir 1985b) associated with the major folding event in this greenstone belt. As such, these rocks are most useful in helping delineate major and minor fold structures associated with that event.

INTRUSIVE ROCKS

Numerous dikes are locally present throughout the stratigraphic pile. On average there is probably at least one dike for every 10 m of the present stratigraphic section. Most dikes are parallel or subparallel to the main regional planar cleavage and can locally

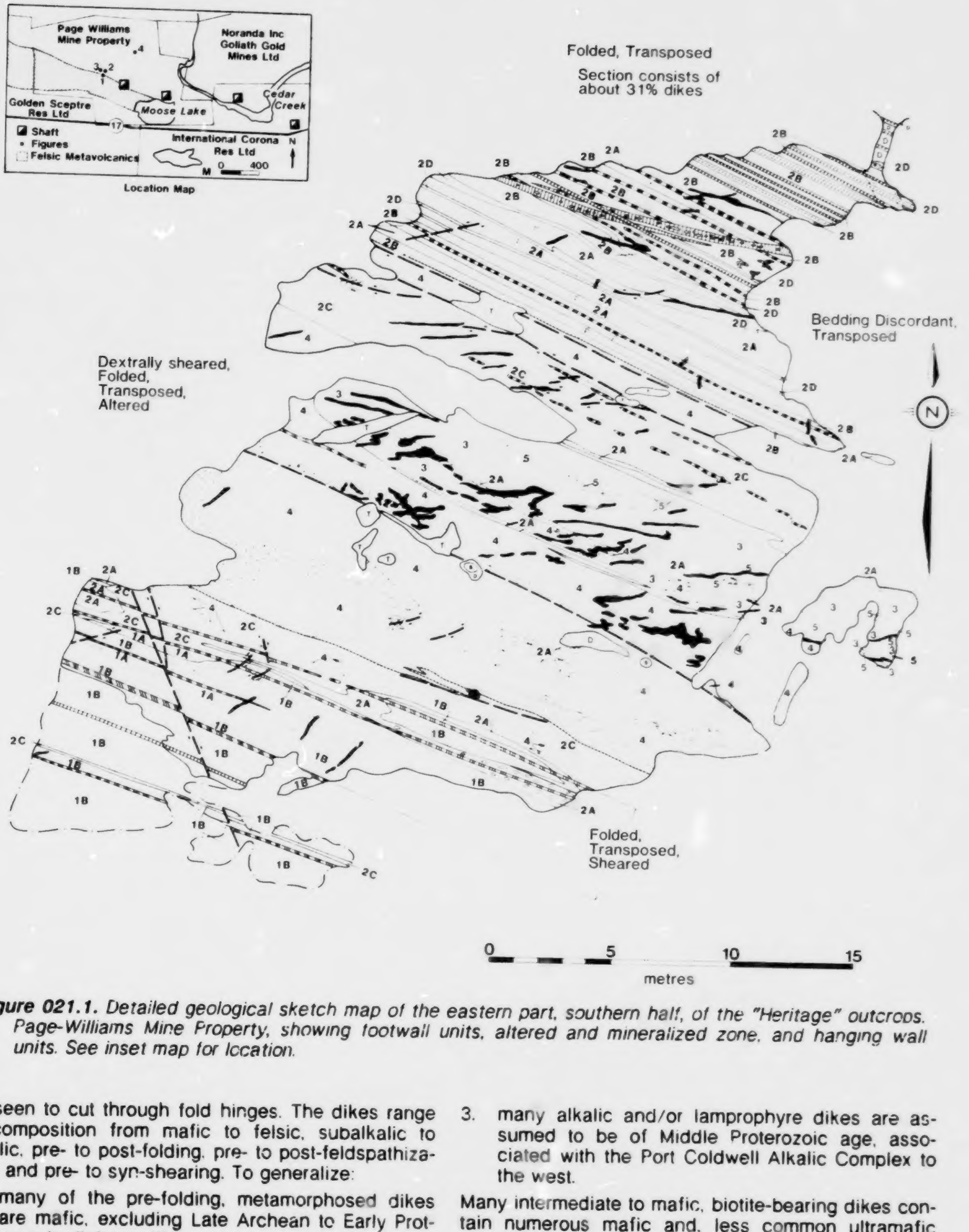

Page Williams
Mine Property
Noranda Inc
Goliath Gold
Mines Ltd
Cedar
Creek
Golden Sceptre
Res Ltd
Moose Lake
17
Shaft
Figures
Felsic Metavolcanics
International Corona
Res Ltd
N
M
0
400
Location Map
Folded, Transposed
Section consists of
about 31% dikes
Bedding Discordant,
Transposed
Dextrally sheared,
Folded,
Transposed,
Altered
Folded,
Transposed,
Sheared
N
1A
1B
2A
2B
2C
2D
3
4
5
0
5
10
15
metres

Figure 021.1. *Detailed geological sketch map of the eastern part, southern half, of the "Heritage" outcrops. Page-Williams Mine Property, showing footwall units, altered and mineralized zone, and hanging wall units. See inset map for location.*

be seen to cut through fold hinges. The dikes range in composition from mafic to felsic, subalkalic to alkalic, pre- to post-folding, pre- to post-feldspathization, and pre- to syn-shearing. To generalize:

1. many of the pre-folding, metamorphosed dikes are mafic, excluding Late Archean to Early Proterozoic diabase dikes
2. many of the post-folding dikes are intermediate to felsic in composition and plagioclase porphyritic or sub-porphyritic (Figures 021.2 and 021.3)
3. many alkalic and/or lamprophyre dikes are assumed to be of Middle Proterozoic age, associated with the Port Coldwell Alkalic Complex to the west.

Many intermediate to mafic, biotite-bearing dikes contain numerous mafic and, less common ultramafic xenoliths (*see* below).

There are at least two pre- to syn-deformation intrusion breccia bodies within the quartz-feldspar-porphyritic complex, one of which has been described by Valliant *et al.* (1985). They have, as their matrix, a fine- to medium-grained, foliated, biotite-

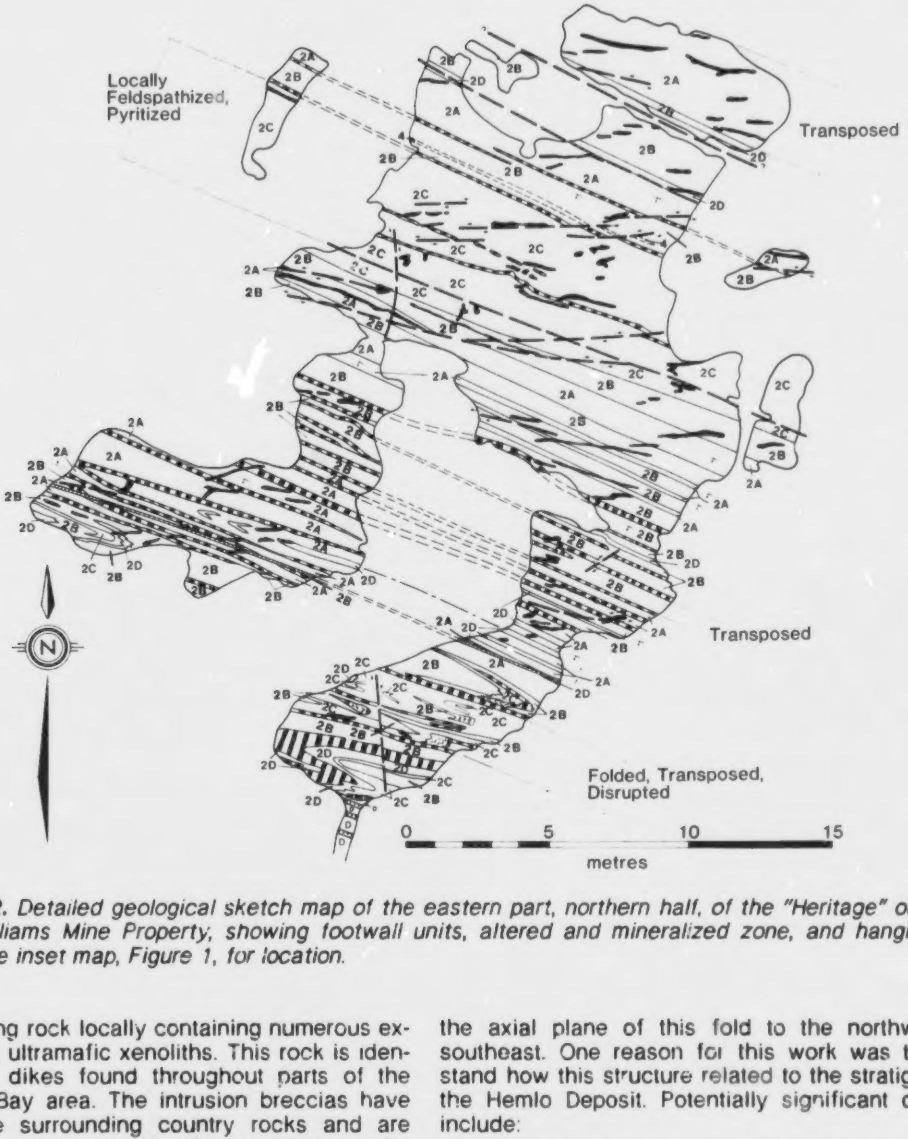


Figure 021.2. Detailed geological sketch map of the eastern part, northern half, of the "Heritage" outcrops, Page-Williams Mine Property, showing footwall units, altered and mineralized zone, and hanging wall units. See inset map, Figure 1, for location.

feldspar-bearing rock locally containing numerous exotic mafic and ultramafic xenoliths. This rock is identical to some dikes found throughout parts of the Hemlo-Heron Bay area. The intrusion breccias have torn apart the surrounding country rocks and are spatially very near zones of gold-molybdenum mineralization. In one case, molybdenum was found in the matrix. Although the author does not, at this stage, consider these bodies to be genetically related to the Hemlo Deposit, more information is needed to verify this point.

STRUCTURAL GEOLOGY

FOLDING

A major west-closing, northwest-plunging reclined antiformal syncline, best delineated on the Page-Williams Mine Property, was reported last year (Muir 1985b). A locally developed, pervasive, axial planar, pressure solution cleavage is associated with this folding. Much of this season's work centred on documenting similar features elsewhere in the map area, and on trying to further delineate the trace of the axial plane of this fold to the northwest and southeast. One reason for this work was to understand how this structure related to the stratigraphy of the Hemlo Deposit. Potentially significant questions include:

1. whether the fold is part of a large 'Z'-shaped, 'M'-shaped, or 'S'-shaped structure
2. whether an inferred east-closing "mate" has been dislocated
3. whether the deposit itself formed prior to folding or whether the host rocks to the deposit had been folded before the deposit formed.

The attempt to trace the fold axis to the northwest met with limited success because of poor exposure and the absence of a well-developed axial planar cleavage. However, the axial planar cleavage described above as well as small-scale folds (Photo 021.2) were noted in numerous other places within this season's area of study to the east and west of the deposit, which indicates that other larger scale folds are present. Insufficient information precludes the preparation of a sketch map of the detected

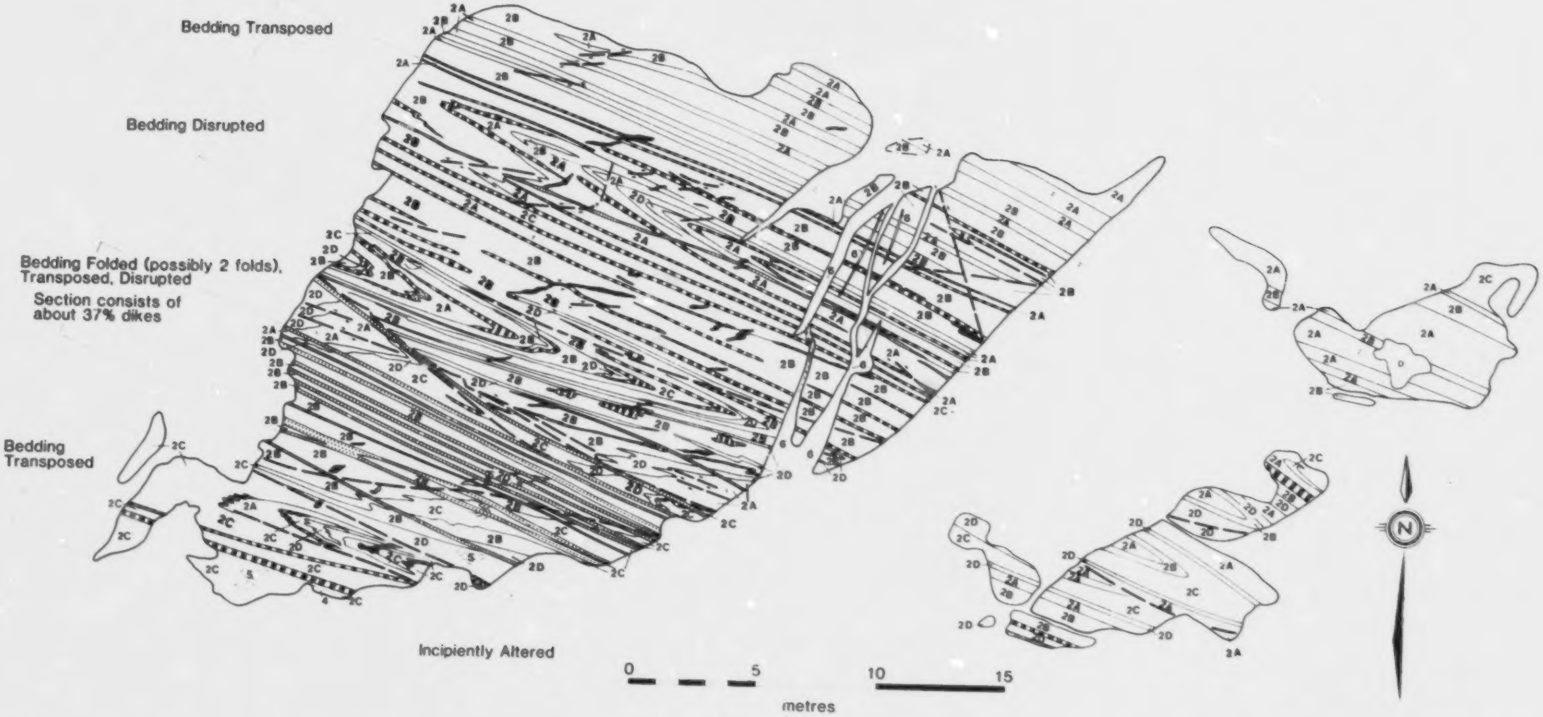

Bedding Transposed
Bedding Disrupted
Bedding Folded (possibly 2 folds), Transposed, Disrupted
Section consists of about 37% dikes
Bedding Transposed
Incipiently Altered
2A
2B
2C
2D
5
6
D
0
5
10
15
metres
N

Figure 021.3. Detailed geological sketch map of the western part of the "Heritage" outcrops, Page-Williams Mine Property, showing folded and locally altered hanging wall units. See inset map, Figure 1, for location.

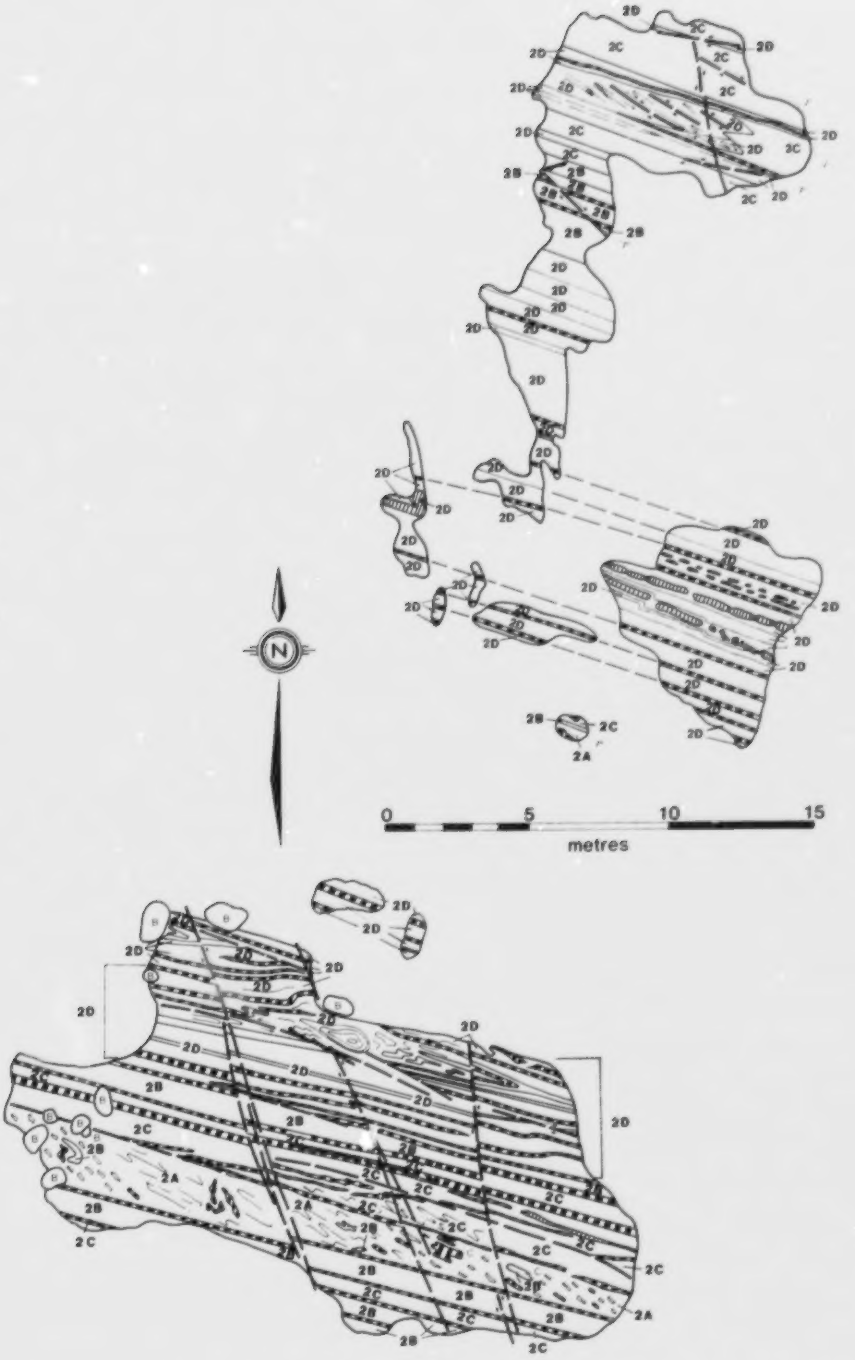


Figure 021.4. *Detailed geological sketch map of some outcrops on the northern limb of a major isoclinal fold, Page-Williams Mine Property. See inset map, Figure 1, for location.*

folding at this time, but it appears that from two to four major folds may be present to the west of the Hemlo deposit. The northern limbs of these folds are overturned (from bedding-cleavage relationships) and in almost every case, where top directions were determinable, the information supports the reclined antiformal syncline/ synclinal antiform configuration of the main fold noted above, and of the northeast-plunging fold on Highway 17 west of Cedar Creek (*see* Muir 1985b).

LEGEND

	PROTEROZOIC
6	Lamprophyre: biotite, pyroxene
	ARCHEAN
▬	Quartz, veins and pods: ±tourmaline±muscovite±chlorite± kyanite±pyrite
	Alteration
5	Feldspathized: locally identifiable as epiclastic and volcaniclastic metasediments
4	Feldspathized and Pyritized: locally identifiable as epiclastic and volcaniclastic metasediments
3	Feldspathized and Biotitized: locally identifiable as epiclastic and volcaniclastic metasediments
	Intrusions
▤	Felsic dike: feldspar, quartz, sericite
▨	Intermediate dike: biotite, feldspar
▥	Mafic dike, gabbro: xenoliths shown where significant
	Metasediments[1]
▮▮▮▮▮	Calc-silicate
2D	Siltstone
2C	Wacke
2B	Arenite: largely volcaniclastic
2A	Conglomerate, granule and pebble: largely volcaniclastic
	Metaporphyries
1B	Felsic, sericitic, quartz-feldspar porphyry: flow?, hypabyssal intrusion?
1A	Felsic, sericitic, quartz-feldspar porphyritic pyroclastic rock

[1] Colour shown represents the dominant lithology within delineable packages of metasediments

	Symbols
⬭	Outcrop outline: 1986 mapping
⬯	Outcrop outline: 1985 mapping
⬯	Outline of pervasively altered delineable units of conglomerate
⬯	Outline of specific features in altered zone (see pattern)
▭	bedding destroyed, very fine grained: locally with molybdenite
▭	highly schistose, fissile on outcrop surface
▨	limonite covered
—	Limits of pervasive alteration
—	Fault: sense shown where determined
-·-	Fold axis: trace of unexposed axial plane
⊥	Bedding top directions: upright facing, overturned
≈	Local bedding or fabric trends
- - -	Inferred extension of units with distinctive similar features
T	Till: cemented
D	Dirt: overburden
B	Boulder: erratic
C	Clast: composite

Table 021.1. Legend for Figures 021.1 to 021.4.

Critical to the above interpretation is knowledge of the overall facing direction in the Hemlo greenstone belt. It is commonly assumed that the belt youngs northward. To date, scattered top determinations documented in this study throughout the map area are dominantly south facing. However, more information is needed; the author does not rule out the possibility that selectively enhanced preservation of textures in overturned units may skew the results in favour of a perceived south-facing stratigraphy. If it can be shown the major fold in question forms an 'S' configuration then the belt must be south facing. In contrast, if it forms a 'Z' configuration the belt must be north facing, and if it is part of an 'M'-fold system, the matter is unresolved.

An examination of outcrops on Highway 17 at the turnoff to the Teck-Corona Mine revealed that within an apparent stratigraphic thickness of less than 75 m (measured horizontally), there are three observed north-plunging folds (with undetermined amplitudes); three more are required to explain all the observed bedding/cleavage relationships within this section. This style of very tight isoclinal folding is consistent with that observed on the so-called "Heritage" outcrops on the Page-Williams Mine Property (Valliant *et al.* 1985; Walford *et al.* 1986; Figures 1 to 3). However, the stratigraphy at these two localities, which are 2.5 km apart, does not appear to be along regional strike, further complicating correlation from place to place.

An examination of the metamorphosed pelitic sediments structurally overlying the Barren Sulphide Zone (*see* Patterson 1984), as exposed on Highway 17, reveal folding which was previously unreported. The rocks appear to form a partly disrupted east-plunging 'Z'-shaped fold with an amplitude of 17 m. Although this configuration initially appears to be consistent with dextral shearing as indicated by stretch and fold axis lineations, the style and degree of development of the axial planar cleavage, the scale of folding, and the cleavage/shearing fabric relationships are more consistent with a major folding event which preceded but was locally superposed by a dextral shearing event. The interval between the two "events" is of unknown duration; they may have been part of a long-lasting, progressive deformation system. At present, the relationship between this fold and the major fold on the Page-Williams Mine Property is unclear.

An examination of metasediments along Highway 17, in the vicinity of the mainland lower mineralized

CENTIMETRE

Photo 021.4. *Veinlets of tourmaline and bleached (feldspathized?) wall rock intruded by east-southeast-trending quartz veins in hanging wall folded metasediments. The view is to the north.*

dicating formation pre- or syn-regional deformation

2. to randomly oriented crystals on schistosity planes (including some planes within some of the mineralized/feldspathized ore host rocks), indicating formation under static conditions, presumably post-shearing within the host rock

Locally quartz veins are observed to have intruded tourmaline veins (Photo 021.4).

Carbonatization has also occurred locally. It has produced disseminated to locally concentrated iron-bearing carbonate which constitutes up to 35 percent estimated abundance in rocks that have been invariably feldspathized, and variably biotitized.

Relatively late quartz pods and veins, generally east-northeast to east trending, are commonly found containing combinations of feldspar, tourmaline, muscovite, chlorite, kyanite, calcite, or pyrite. Kyanite in these veins, as opposed to groundmass kyanite in the country rocks, can be found up to 600 m from the main zone of feldspathization. In many cases it is partly to completely altered (retrograded?) to an opaque, white mineral and/or muscovite, suggesting that late fluids during the waning stages of alteration/metamorphism were somewhat potassic and hydrous.

U–Pb GEOCHRONOLOGY

The preliminary results of five U-Pb dates for rocks of the Hemlo area were presented this year (Corfu and Muir 1986). Six additional samples were selected this season by the author and Fernando Corfu from the area between Hemlo and Heron Bay. Samples collected were from:

1. volcanic rocks at Heron Bay
2. major granitoid bodies such as the Pukaskwa Complex, the Heron Bay Pluton, and the Gowan Lake Pluton
3. a highly recrystallized amphibolite, which was included in the study in an attempt to fix an age for peak metamorphism.

PRELIMINARY REGIONAL STRUCTURAL SYNTHESIS

A cursory examination of some regional structural aspects was undertaken, by the author and Greg Stott at the beginning of the season. The tentative findings which, will serve as starting points for subsequent studies, are as follows.

The outer margins of the Pukaskwa Gneissic Complex have a pronounced planar fabric (Muir 1982) which has an associated mineral lineation corresponding to the mineral lineation in the adjacent supracrustal rocks. This fabric extends at least a few kilometres into the supracrustal rocks and is possibly a strain aureole associated with diapiric intrusion of the main phase(s) of the complex. The rocks in the Gneissic Complex, within at least 2 km of the outer contact (the distance into the complex over which observations were made) do not appear typical of gneisses and tonalites from well documented basement complexes.

The Cedar Lake, Gowan Lake, and Heron Bay Plutons do not appear to be notably metamorphosed. These plutons lack well developed planar fabrics. Mineral lineations are weak with the exception of the major phase of the Gowan Lake Pluton which has a moderately well developed mineral lineation (hornblende) that may be the result of primary flow alignment. The plutons also appear to have imposed a minimal strain aureole on the adjacent supracrustal rocks, which suggests that stoping was the main mechanism of intrusion.

The Heron Bay shear zone, which appears to be dextral in sense, has had a complicated history. Rocks in the zone display at least two sets of crenulation cleavages. South of the Town of Heron Bay the rocks are highly flattened and there are indications of minor(?) pervasive sinistral shear, possibly reflecting proximity to the western termination of the Heron Bay Pluton to the southeast. Elsewhere, such as near the Middle Proterozoic Port Coldwell Alkalic Complex and at the northeastern termination of the Heron Bay Pluton, well developed, dextral shear fabrics have been produced. This may relate to a major dextral shear system, part of which is spatially associated with the Hemlo Deposit.

CONCLUSIONS

Initial exploration and investigation of the Hemlo gold Deposit and its setting, in the early 1980s, resulted in its interpretation as a relatively undeformed, homoclinal sequence of Archean metavolcanic and metasedimentary units containing a conformable, syngenetic (exhalative or hot spring), gold-bearing sinter deposit. Recently, more detailed surface mapping, drill core logging, and work in three mines, has led to recognition of major lithological, structural, and alteration features which have raised significant questions about the syngenetic model. Mounting evidence, some of which is summarized below, strongly supports an epigenetic origin for the gold deposit. The author thinks that the Hemlo Deposit is clearly not syngenetic. What is not clear, however, is the timing and role of shearing, metamorphism, and alteration in the formation of the deposit.

No siliceous sinter has been found at Hemlo. Potassic feldspathization is the dominant form of alteration of the mineralized volcanic and sedimentary rocks, along with sericitization, biotitization, carbonatization, tourmalinization, and pyritization in association with gold, molybdenum, and barium mineralization. The bedded character of the barite associated with the deposit is questionable; although it does appear to be stratiform elsewhere in the greenstone belt (*see* Patterson 1984), the barite is almost invariably sheared and, at Heron Bay, is associated with quartz-carbonate veins within a dextral shear system.

Gold and molybdenum are present in the western part of the deposit within an intermediate to felsic quartz-feldspar-porphyritic complex likely comprising extrusive and hypabyssal rocks, and in the eastern part of the deposit within laminated metasediments which are locally highly folded and transposed, and which show evidence of tectono-metamorphic banding. As such, the mineralization crosscuts stratigraphy over a strike length of a few kilometres.

Major folding of the supracrustal rocks has taken place. This is clearly evident:

1. in rocks structurally overlying and underlying the deposit where isoclinal, reclined, antiformal synclines and synformal anticlines have been delineated
2. locally in rocks hosting the mineralization where the same fold style has been superposed by shear folding accompanied by considerable transposition, attenuation, and dislocation

Some or all of the host rocks to the mineralization may thus also be overturned. Structurally overlying the eastern part of the metasediment-hosted orebody are pelitic metasediments containing several alteration/metamorphic minerals (for example, anthophyllite, cordierite, staurolite). The spatial association of these rocks with the orebody is a result of their constrained configuration within the centre of the tightly folded major west-closing antiformal syncline, which therefore limits the apparent strike extent of this unit. This unit is likely not a result of localized syngenetic alteration of sediments.

The isoclinal folding is here interpreted to be the result of regional deformation. It predates, by an undetermined interval, and is not a result of, dextral shearing which is manifest as several strongly to intensely deformed zones, one of which hosts the orebody and which was superposed on the folded country rocks, possibly within a progressive deformation system. Shearing is incipiently developed locally between these highly deformed zones, and has also affected the mineralization. At least some, if not all, of the feldspathization, and likely the other forms of alteration listed above, post-date the isoclinal folding event. Feldspathization and tourmalinization have affected large volumes of country rock extending for hundreds of metres into the country rock, both structurally above and below the orebody, in overturned and upright-facing stratigraphy.

Dislocation along bedding planes and isoclinal fold limbs, caused by dextral and sinistral faulting that resulted from folding and/or the predominantly dextral shearing event, is evident in small- and medium-scale structures. This suggests that bedding dislocation may have occurred on a mega-scale, which may be one of the reasons why stratigraphy cannot be matched consistently across major fold axes. Notable vertical displacement is also a possibility in some cases.

Transposition due to folding and/or shearing is present, particularly within noses of small- to medium-scale, tight isoclinal folds. However, this feature has likely not developed on a scale large enough to affect significant proportions of the supracrustal rocks because many distinguishable units of deformed pyroclastic rocks, volcaniclastic rocks, and conglomerates can be traced for some distance along strike. It should be noted, however, that the degree of tectonic folding, dislocation, and transposition of these rocks precludes any delineation of primary growth faults in this area.

Tectonic pull-apart features, due to ductility contrast, have locally developed in some tight isoclinal fold noses. The degree to which these tectonic features mimic primary fragmental rocks sufficiently to make their misidentification inevitable is considered minimal. Only one notable unit, which is within the ore deposit, is considered by the author to be a possible tectonic breccia formed due to ductility contrast.

Shearing in the relatively isotropic quartz-feldspar-porphyritic complex appears, locally at least, to control the locus of some of the alteration and mineralization. These shears are related to the zones of strong dextral shearing, and must have been created during a compressional event which involved pressures and stresses well in excess of those possible due to lithostatic loading. Field evidence shows that the host rocks had been deformed and tilted before the shearing and alteration took place and this, coupled with other field evidence, constrains the timing of mineralization to post-deposition and post-folding of the host rocks.

U-Pb zircon dating of several rocks from within and around the deposit shows a 70 to 90 Ma difference between the age of the intermediate to felsic quartz-feldspar-porphyritic complex which locally hosts the mineralization, and the age of major granitic plutonism (for example, Cedar Lake Pluton) and numerous feldspar and quartz-feldspar-porphyritic dikes. However, as yet, no clear causal relationship between the intrusion of any specific type of dike and alteration/mineralization has been established to the author's knowledge.

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022. Mishibishu Lake Area, Districts of Algoma and Thunder Bay

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INTRODUCTION

This report outlines the results of the second year of a three-year program to map the stratigraphy and structure, and examine the mineral occurrences in the Mishibishu Lake Area. The area is approximately 40 km west of Wawa. Access is by float-equipped aircraft to Mishibishu Lake, Katzenbach Lake, and a few smaller lakes. Rugged terrain restricts access to helicopters in many parts of the area.

The 1986 field season was spent continuing mapping started in 1985, and expanding the map area to include the ground encompassed between 85°00'W and 86°00'W Longitude and 47°52'30"and 48°10'N Latitudes. The area mapped in 1986 was approximately 1216 km^2, bringing the total area mapped to 2046 km^2 over two seasons.

The survey consisted of helicopter-assisted detailed mapping of the supracrustal rocks with traverses spaced at 1/4 mile intervals, and reconnaissance mapping of surrounding plutonic areas by short helicopter stops to gather samples and structural data.

Some revision of interpretations was made southeast of Katzenbach Lake and in the David Lakes areas, based on new data. The Mishibishu Deformation Zone has been traced east and west from its previously delineated limits. Several other zones exhibiting extensive structural deformation were also recognized and will be briefly described below.

Five Preliminary Maps were published in 1986 (Bowen *et al.* 1986a, b, c, d, e) based on 1985 field work. None of these were completed in regard to traverse coverage. The 1986 field season saw mapping on these sheets completed, including more detailed work in some areas. Two additional map sheets were completed and parts of five more sheets were mapped to fully cover the extent of the supracrustal belt.

Information on mineral occurrences was gathered from the Assessment Files, Resident Geologist's Office, Ontario Ministry of Northern Development and Mines, Sault Ste. Marie, and the Assessment Files Research Office (AFRO), Ontario Geological Survey, Toronto.

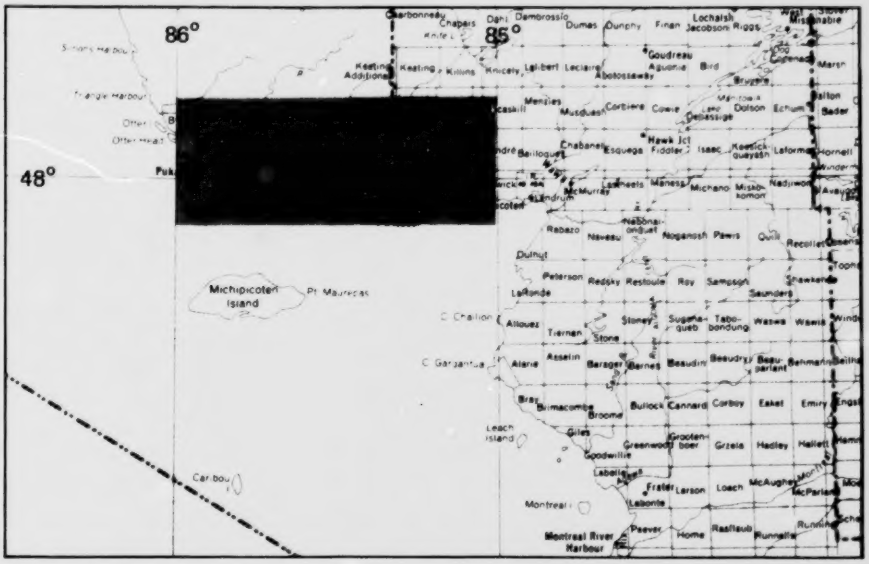
MINERAL EXPLORATION

Previous exploration activity has been described in Bowen and Logothetis (1985), Heather (1985), and Bowen *et al.* (1985a, b, c, d, e).

During the past year Muscocho Explorations Limited has extended an all-weather road to their property north of Mishibishu Lake, and has begun an exploration decline in order to extract a bulk sample from their drill-indicated gold-bearing zone.

Granges Exploration Limited has performed soil sampling and ground VLF-EM, and is presently conducting an extensive diamond drilling program on their MacMillan Energy Group option property, situated west and southeast of the Muscocho Explorations Limited ground.

Durham Resources Incorporated has continued work, including some diamond drilling on their



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

Scuzzy Little Lake claims, and has optioned its Missing Lake group to Noranda Exploration Company Limited who has begun a Fall exploration program.

Further details of the Muscocho Explorations Limited and Granges Exploration Limited properties refer to the summary by K.B. Heather (this volume).

GENERAL GEOLOGY

ARCHEAN

The supracrustal rocks are Late Archean in age and make up approximately 60 percent of the rocks underlying the map area. The volcanic rocks apparently consist of a single volcanic sequence of mafic, massive, and pillowed flows and pyroclastic rocks of magnesium tholeiite, iron tholeiite, and calc-alkalic affinity. Numerous thick, gabbroic-textured flows and synvolcanic sills and dikes were noted in the course of mapping. Coarse porphyritic "leopard rock" was found throughout the map area. Preliminary analysis of whole rock geochemical data using the Jensen Cation Plot, AFM diagram, and several binary plots, indicate that the metavolcanics were likely to have been derived from a single source.

Intermediate and felsic flows and pyroclastic rocks are intercalated with the mafic metavolcanics. The pyroclastic units are generally quite thin, 1 to 5 m thick. Some of these may be hypabyssal sills; however, exposed contacts exhibiting intrusive characteristics were rarely observed, whereas sharp, conformable contacts with both mafic metavolcanic and metasedimentary units are common.

Chemical metasediments occur only within the metavolcanic sequence or at the interface with clastic metasediments. They comprise mostly magnetitic chert interbedded with magnetite ironstone. Sulphidic (pyrite) and graphitic units are less common. In places these chemical metasedimentary units are extremely contorted and even brecciated. Some prospecting for iron ore was done in the past (Bell 1905; Coleman and Willmott 1899), however, tonnage and grade were found to be low.

Clastic metasediments include polymictic matrix- and clast-supported conglomerates, oligomictic quartz pebble and granule conglomerates, wacke, arkose, and laminated mudstones. Preliminary interpretation of field evidence suggests that the supracrustal and batholithic areas were subjected to rapid uplift and erosion and that the sedimentary units are submarine fan type deposits, mostly turbidites.

Coarse-grained mafic rocks were encountered in several areas; some are clearly intrusive, while others are equivocal in origin. They may be thick mafic flows or synvolcanic sills and dikes.

Felsic to intermediate hypabyssal units were observed in several locations, and for the most part occur as sills and dikes. Typically, they are feldspar porphyritic monzonite and quartz-feldspar porphyritic granite. Some of the porphyritic units appear quite melanocratic and may be dioritic.

External batholiths enclose the supracrustal rocks completely. From data collected in the 1985 field season, these batholiths are complex bodies known to contain foliated to gneissic biotite and muscovite-biotite tonalite-quartz diorite, foliated to gneissic hornblende and biotite-hornblende diorite-tonalite which occurs as inclusions within the biotite tonalite and quartz diorite, hornblende and hornblende-pyroxene granite, and quartz monzonite.

The Bowman Lake Batholith is a complex of massive to foliated biotite and muscovite-biotite granodiorite to granite with lesser tonalite. The other internal granitoids form discrete and largely homogeneous plugs. The Central Pluton is a porphyritic biotite and muscovite-biotite monzogranite and granodiorite. The Mishibishu Lake Stock, situated around Mishibishu, Mishi, and Katzenbach Lakes, is massive pyroxene and hornblende-pyroxene monzonite to quartz monzonite. Specular hematite and magnetite are common, and the stock appears as a magnetic high on aeromagnetic maps.

There is some indication, through U-Pb dating of zircons (Turek *et al.* 1984), that the northern batholithic complex may be older than the supracrustal rocks; however, the Central Pluton and the Mishibishu Lake Stock clearly intrude the supracrustal rocks.

Archean diabase dikes cut all the rock units mentioned above. Several crosscutting relationships were observed along the shore of Lake Superior; an older north-south set of dikes are cut consistently by a northwest-southeast set. Dates recorded by Wanless *et al.* (1965) of 2492 Ma and Lowdon *et al.* (1963) of 2487 Ma; however, indicate that they may be fairly close in age. Several northeast-trending diabase dikes were mapped but no crosscutting relationships were observed.

Regional metamorphism is greenschist facies rank with amphibolite facies rank reached near the contact with stocks and batholiths.

Pleistocene deposits are generally confined to clays and tills up to several tens of metres thick. Some esker and outwash deposits were noted and several raised beaches can be counted near the shore of Lake Superior. Organic cover is generally only a few centimetres thick.

PROTEROZOIC

Mafic diatremes occur in a few areas, and several flat lying amygdaloidal basalt flows unconformably overlying steeply dipping Archean rocks were noted. Similar flows on Michipicoten Island range in age from 1004 Ma to 918 Ma (Wanless and Loveridge 1978).

STRUCTURAL GEOLOGY

The major structure in this area is a broad, east-trending, eastward plunging synform, the axis of which roughly bisects the supracrustal belt. The axial plane of this major fold is inclined to the south, and the axial trace is arcuate, convex to the north. Plagioclase-phyric basalt flows are useful marker horizons on both limbs of the fold, but unequivocal top indicators are not common, making small scale structures difficult to delineate. Parasitic synclines and anticlines, subparallel to the main fold, are, however, indicated by repetition of supracrustal stratigraphy, particularly on its northern limb. This is most evident along the shore of Lake Superior near the southeastern contact between the supracrustal rocks and felsic batholithic rocks just west of McCoy's Harbour.

The supracrustal rocks have also been affected by a number of strata-parallel, brittle-ductile deformation zones, the most notable of which has been termed the Mishibishu Deformation Zone (Heather 1985). This structure consists of a number of discrete subparallel zones of highly sheared and variably altered rock separated by areas of far less deformed rock. The Mishibishu Deformation Zone is 200 to 500 m wide, as defined by the most deformed and altered rocks. Most of the intense deformation occurs in clastic metasediments along primary lithological contacts. The most intense deformation, alteration, and the largest gold deposits found to date, occur proximal to the Mishibishu Lake Stock; however, elements of the deformation zone can be traced east and southeastward as far as Lake Superior and as far west as David Lakes (Heather, this volume). Kinematic indicators, such as clast and mineral lineations, slickensides, step fractures, rotated augen, drag folds, suggest that the movement was dominantly right-handed along the component shears within this deformation zone.

Less extensive strata-parallel deformation zones have been identified in the Rook Lake and Eagle River areas (*see* Heather, this volume). Again, in those areas the component shear zones tend to follow lithological contacts such as those between clastic metasedimentary and mafic or felsic metavolcanic units. The total width and intensity of deformation/alteration along these two zones is much lower than that seen in the Mishibishu Deformation Zone, but they do deserve attention as potential gold-bearing structures. Their presence also raises the possibility of additional, as yet unidentified, shear zones in the same orientation.

Stratigraphy and brittle-ductile deformation zones are crosscut, and in some cases offset, by numerous north and northwest-trending faults and fractures. Many of these are now healed by diabase dikes. These fractures may have played a part in localizing gold mineralization along the deformation zones (Heather 1985).

ECONOMIC GEOLOGY

Although base metal and iron exploration has occurred in this belt, gold currently appears to be the only commodity with economic potential. The reader is referred to the descriptions and recommendations of Bowen and Logothetis (1985), Heather (1985), and Heather (this volume) for a summary of the characteristics of local gold deposits, and for information on exploration potential. Suffice it to say here that known gold deposits in the area are closely structurally controlled and are spatially and genetically related to brittle-ductile deformation zones. Integrated geological-geochemical programs are recommended to narrow down exploration targets within and along strike with these zones. More work should be done to "fingerprint" the character of alteration associated with gold deposits.

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023. Geology of Cassels and Riddell Townships, District of Nipissing

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

The map area (186 km^2) consists of Cassels and Riddell Townships and is located 5 km east of Temagami in the District of Nipissing. It is bounded by Latitudes 46°58′25″N and 47°08′00″N and Longitudes 79°38′00″W and 79°45′20″W.

Road access to the area is limited to two gravel roads which lead from Highway 11 to Cassels Lake. One is in Cassels Township and provides access to Temagami, the other is Lowell Lake Road in Riddell Township. Road access to the northern part of Cassels Township is via a four-wheel drive road along a major power transmission line.

The Ontario Northland Railway cuts across the southwestern corner of Riddell Township and provides some additional walking access.

Cassels, Rabbitt, Pishabo, and Net Lakes provide water access to most other parts of the map area.

MINERAL EXPLORATION

The information reported here, if not stated otherwise, is taken from the assessment files, Resident Geologist Office, Cobalt, Ontario.

Mineral exploration for silver and cobalt in Cassels Township dates from 1900 with shaft sinking and trenching by Temagami-Lorrain Mining Limited in the Sauve Lake area and Temagami-Cobalt Mining Company Limited in the Gosselin Lake area. During this period a smaltite-bearing vein was discovered along the Ontario Northland Railway in Riddell Township.

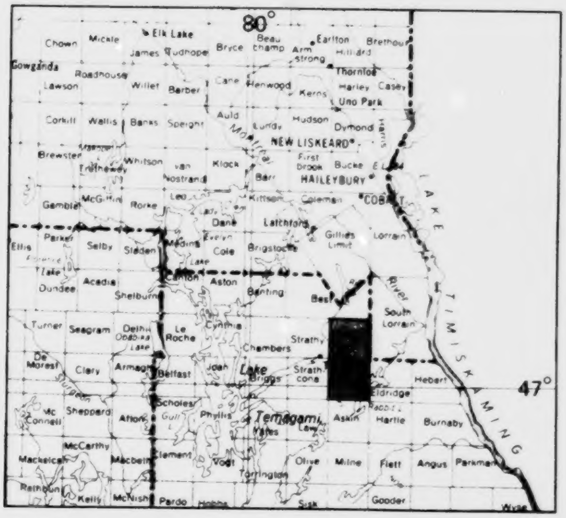
Base-metal exploration by Hermes Mines Limited in 1945 was centred on the Boot Bay and Outlet Bay areas of Net Lake in Cassels Township. This work consisted of 10 diamond-drill holes (801 m) at three locations.

Exploration for silver and cobalt near Gosselin Lake by E. deCamp in 1954 resulted in trenching and follow-up drilling of five holes for a total length of 365 m.

Base-metal exploration during the 1950s consisted of several diamond-drill programs on known sulphide occurrences in Cassels Township. Five holes (totaling 178 m) were drilled by A. Brochu in 1955 on the Hermes copper occurrence just east of Outlet Bay, and six holes (totaling of 151 m) were put down by B. Riopel in 1955 on an occurrence on a peninsula of Cassels Lake.

Ground geophysical surveys and drilling (one 183 m hole) were carried out by Geo-scientific Prospectors Limited in 1956 adjacent to Obashkong Lake. Twenty trenches and 11 drillholes for a total of 445 m were put down by New Athona Mines Limited in an area northeast of Outlet Bay. A ground geophysical survey was carried out in 1962.

The Gosselin silver-copper Property near Gosselin Lake was extensively explored by Aldage Mines Limited in 1963. The work consisted of geological and geophysical surveys, prospecting, trenching and


80°
47°
Elk Lake
Gowganda
NEW LISKEARD
HAILEYBURY
COBALT
Temagami
LAKE TIMISKAMING
Montreal River
Chown
Mickle
James
Tudhope
Bryce
Beauchamp
Armstrong
Earlton
Brethour
Hilliard
Thornloe
Lawson
Roadhouse
Willet
Barber
Cane
Henwood
Kerns
Harley
Casey
Uno Park
Corkill
Wallis
Banks
Speight
Auld
Lundy
Hudson
Dymond
Harris
Brewster
Trethewey
Whitson
van Nostrand
Klock
Firstbrook
Bucke
Barr
Gamble
McGiffin
Rorke
Leo
Kittson
Coleman
Dane
Latchford
Gillies Limit
Lorrain
Ellis
Parker
Selby
Sladen
Medina
Evelyn
Cole
Brigstocke
Dundee
Acadia
Shelburn
Canton
Aston
Banting
Best
South Lorrain
Turner
Seagram
Delhi
Obabika Lake
Le Roche
Cynthia
Strathy
Chambers
De Morest
Clery
Armagh
Belfast
Joan
Briggs
Strathcona
Hebert
Eldridge
Mc Connell
Sheppard
Afton
Scholes
Phyllis
Yates
Askin
Hartle
Burnaby
McCarthy
Mackelcan
Macbeth
Clement
Vogt
Torrington
Olive
Milne
Flett
Angus
Parkman
Rathbun
Kelly
McNish
Pardo
Hobbs
Sisk
Gooder
Wyse

LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

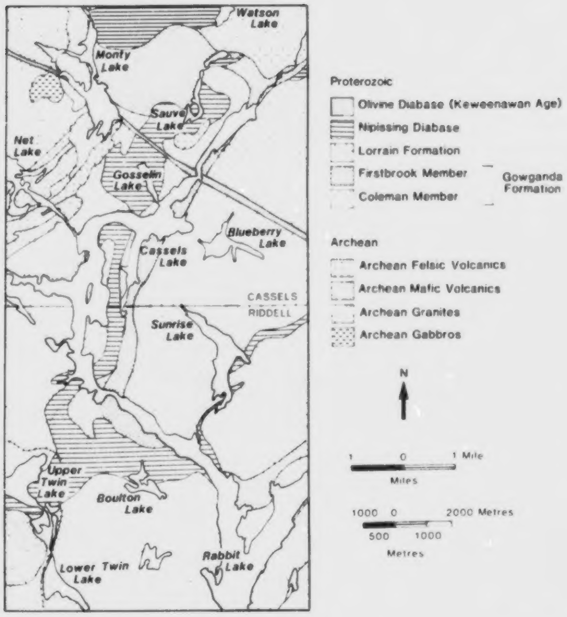


Figure 023.1 *General Geology of Cassels and Riddell Townships.*

sampling, and subsequent diamond drilling of 10 holes for a total of 331 m.

Soil geochemical and geophysical surveys on adjacent claims were completed in 1964 by D. Burton.

Other work in 1964 consisted of three diamond-drill holes (totaling 107 m) by E. Burke on a galena showing at Boulton Lake in Riddell Township.

Airborne geophysical surveys were carried out by Keevil Mining Group in 1965 over the western half of Cassels Township. Later, follow-up geophysical surveys and diamond drilling were carried out by Wabi Mining Syndicate in 1968 on the former New Athona Property, northeast of Outlet Bay. The following year, Rio Tinto Canadian Exploration Limited carried out geological and geophysical surveys and diamond drilling five holes totaling 605 m in length on the same property. Elsewhere in the area, a soil geochemical survey and diamond drilling of nine holes (554 m) were completed in 1969 by Silver Leader Mines Limited on a property to the east of Bogie Lake. Ground geophysical surveys by Metron Exploration Limited in the southwestern corner of Riddell Township, and by Beaverhouse Mines Limited in the Boot Bay area of Cassels Township, were completed between 1970 and 1971.

Geological surveys, trenching, and three diamond-drill holes (totaling 705 m) were completed by Goldex Mines Limited in 1973 near a chalcopyrite showing along the Gowganda Formation-Nipissing Diabase contact at Boulton Lake in Riddell Township.

Elsewhere in Riddell Township, several trenches were put down during 1974 in Archean mafic metavolcanics west of Lower Twin Lake by G. Vaillancourt.

Geological mapping by Canadian Nickel Company Limited in 1974 and ground geophysical surveys by Hollinger Mines Limited and St. Joseph's Exploration Limited in 1978 were carried out northeast of Outlet Bay in Cassels Township.

GENERAL GEOLOGY

The first geological mapping of the area was done on a reconnaissance scale by Bell (1892), Barlow (1899), Coleman (1900), Miller (1901), Burrows (1909), Miller and Knight (1911), Knight (1919), and Todd (1925). Subsequent and more detailed mapping in areas adjacent to Cassels and Riddell Townships were carried out by McIlwaine (1970), Bennett (1978), and Fyon and Crockett (1986).

Underlying the map area are Archean supracrustal and plutonic rocks, Middle Proterozoic supracrustal and intrusive rocks, and Middle Proterozoic (Keweenawan) dikes (Figure 023.1).

Archean rocks which underlie the northwestern part of the map area consist of a 8 km long, northeast-trending metavolcanic belt intruded by Archean felsic and mafic plutonic rocks. The metavolcanic belt is an eastward extension of the Temagami greenstone belt which has been subdivided into a Younger Volcanic Complex (YVC) and Older Volcanic Complex (OVC) (Fyon and Crockett 1986). Archean metavolcanics in Cassels Township are part of the YVC whereas those found in the southwest corner of Riddell Township are part of the OVC. The oldest rocks in the Net Lake area (Cassels Township) are pillowed to massive mafic flows of the Arsenic Lake Formation (Fyon and Crockett 1986) which are found along the northern limb of the Lake Tetapaga syncline. Overlying these are mainly intermediate to felsic pyroclastic rocks such as tuffs, lapilli-tuffs, lapillistone with minor mafic to intermediate, and intermediate to felsic flows which correspond to the Link Lake Formation. The youngest rocks are pillowed to massive mafic flows of the Upper Formation which occupy the core of the syncline. Clastic rocks of the Turtle Lake Formation which normally overlie the Link Lake Formation further to the west, appear to be absent in Cassels Township.

Rocks of the Older Volcanic Complex outcrop west of Lower Twin Lake in southwest Riddell Township and consist of well-foliated massive and pillowed mafic flows and minor pyroclastic rocks.

A body of coarse-grained gabbro, pyroxenite, amphibolite, and minor pillowed mafic volcanic rocks represents a mafic volcanic-plutonic remnant in the Archean granitic terrain west of Pishabo Lake in Cassels Township.

Felsic plutonic rocks consist of coarse-grained, massive leucocratic granites with minor granodiorite and trondhjemite varieties. A contaminated border zone is locally present and exhibits up to 50 percent mafic xenoliths.

North- and northwest-trending mafic dikes commonly intrude the felsic plutonic rocks. These consist of diabase and minor lamprophyre and plagioclase porphyritic diabase which are referred to as Matachewan dikes by Todd (1925).

Early Proterozoic rocks of the Huronian Supergroup, namely the metasediments of the Gowganda and Lorrain Formations, underlie most of the area.

The Gowganda Formation consists of a lower unit, the Coleman Member, and an upper unit, the Firstbrook Member.

Coleman Member rocks unconformably overlie the Archean basement and are approximately 500 m to 600 m thick. These rocks consist of a local basal breccia of angular granitic clasts, overlain by matrix- and clast-supported granitic clast conglomerates which grade upwards into predominant pebbly wacke. Locally, however, laminated to thinly bedded siltstones, pebbly siltstones, and pebbly arkose are intercalated with massive to thickly bedded pebbly wacke.

Coleman Member rocks are characterized by rapid lateral lithofacies changes and the presence of "dropstones". Contacts between the Coleman and overlying Firstbrook Member are poorly exposed but appear to be conformable and abrupt. The transition is marked by the disappearance of granitic clasts and/or 1 to 2 mm quartz grains within the rocks and by an abrupt changes in bedding and lithology to laminated grey to maroon siltstones and wackes in the Firstbrook Member.

The thickness of the Firstbrook Member is generally in the range of 100 to 200 m except in the northern part of the map sheet were it is 400 m thick. Contacts between the Firstbrook Member and the overlying Lorrain Formation are conformable and gradational over 10 to 20 m except in one locality at the northern edge of the map area where this is an angular unconformity.

Rocks of the Lorrain Formation, which locally have a thickness of approximately 600 to 700 m, underlie the eastern half and northern margins of the map area. The lower part of the formation consists of thickly bedded green subarkosic wackes interbedded with minor laminated siltstones which grade upwards into laminated subarkosic wackes that commonly exhibit crossbedding and minor graded bedding.

Overlying this is a unit of medium-bedded, coarse- and fine-grained subarkose and subarkosic wacke which is in turn overlain by thickly bedded subarkose and arkose which contain rare pebbly beds.

Early Proterozoic Nipissing quartz diabase forms a north-trending, 600 m thick sill which intrudes mainly Coleman Member and lesser Firstbrook Member and Lorrain Formation lithologies. Contact metamorphism of these sedimentary rocks resulted in local chlorite spotting in Lorrain Formation rocks and local chloritization, epidotization, and recrystallization of Coleman and Firstbrook Member rocks at several localities.

Coarse-textured diabase, variably textured diabase, and minor granophyre are the main lithologies of the slightly differentiated Nipissing Diabase sill.

The youngest Precambrian rocks in the area are represented by northwest-trending, 200 m wide olivine diabase dikes of the Sudbury Swarm which cut across Cassels Township.

STRUCTURAL GEOLOGY

Archean metavolcanics in Cassels Township are folded into a northeast-trending syncline which is the extension of the Lake Tetapaga Syncline (Bennett 1978; Fyon and Crockett 1986). To the south, in Riddell Township, pillowed Archean flows indicate top directions to the east and northeast.

Sedimentary rocks of the Proterozoic Gowganda and Lorrain Formations have undergone two periods of folding. The effects of the first period of folding are mainly evident in the southern half of the map area and are represented by a series of southeast-trending synclines and anticlines between Snake Lake and Rabbit Point on Rabbit Lake. The beds have a gentle dip of 10° to 30° to the north or south. A southeast-trending penetrative schistosity is associated with this folding event. Refolding (F_2) occurred along north- and northeast-trending fold axes which caused a series of gentle basin and domes in the southern half of the map area.

Elsewhere, the F_2 axes are parallel to the original bedding and are represented by local north- and northeast-trending penetrative cleavage/schistosity. The net effect of the F_2 folding was to steepen the attitude of the original beds in the east-facing synclinorium from horizontal to 10° to 45°.

It is believed that the F_1 folding probably occurred during the Penokean Orogeny while F_2 folding was possibly related to the later Grenville Orogeny since its effects are mainly seen in the part of the map area closest to the Grenville Front.

Several shear zones and lineations have been identified. The only major shear zone is the northeast-trending Link Lake Deformation Zone which cuts the Archean metavolcanics of the Lake Tetapaga Syncline in the Boot Bay area of Cassels Township. In other areas, both northeast and northwest strikes of minor shear-zones have been recognized within the younger Huronian sedimentary rocks.

The lineaments strike in two prominent directions; a dominant northwest set, and a lesser northeast set. The northwest-striking set is probably related to the fracturing associated with the development of the Lake Timiskaming Rift System (Lovell and Caine 1970).

The grade of regional metamorphism in the area varies from unmetamorphosed olivine diabase dikes of the Sudbury Swarm to lower greenschist facies (Winkler 1976) in both Archean metavolcanic and Huronian sedimentary rocks.

ECONOMIC GEOLOGY

Copper, gold, and silver mineralization is generally related to the upper margins of the Nipissing Diabase sill in contact with Coleman Member sedimentary rocks of the Gowganda Formation.

Near Sauve Lake on the Temagami-Lorrain Property a 35 m shaft was sunk on a 10 cm wide, southwest-trending calcite-quartz vein with cobaltite, erythrite (cobalt bloom), arsenopyrite, pyrite, and chalcopyrite. The host rocks are variably textured Nipissing Diabase which are locally extensively altered by hydrothermal solutions. Assay results given by Todd (1925) indicate values of 5.87% Co, 0.12% Ni, 1.08% Cu, 10.39% As, 1.08 ounces Au per ton, and trace silver.

A similar geological setting exists at the Gosselin Property near Gosselin Lake where a 53 m shaft was sunk on several northeast-trending calcite-quartz veins. Sulphide minerals present are chalcopyrite and pyrite containing 1 to 11% Cu, 3 ounces Ag per ton and 100 to 3400 ppm Co (Geoscience Laboratories, Ontario Geological Survey, Toronto). A parallel and similar vein on the eastern side of Gosselin Lake is 20 cm wide and contains cobaltite or smaltite, erythrite, nicolite, and annabergite (nickel bloom).

Another northeast-trending, 5 cm wide sulphide vein (800 m north of the shaft) contains chalcopyrite, pyrite, and minor calcite. This vein is along a joint surface in relatively unsheared and unaltered varied textured diabase close to several cross-cutting, aplitic, granophyre veins. Analyses indicate an average grade of 2.67 ounces Ag per ton and 15.76% Cu over a width of 10 cm for a length of 18 m (Assessment Files, Resident Geologist Office, Cobalt). A similar 10 cm wide calcite-quartz vein with disseminated smaltite and pyrite is hosted within the outer margins of the sill in Riddell Township.

Several other localities within the Nipissing Diabase exhibit disseminated sulphide mineralization or host calcite-quartz veins. The sulphide minerals present in both consist of chalcopyrite, pyrite, and galena.

Disseminated sulphides in the diabase are minor, but of interest for potential platinum group element (PGE) mineralization. Several studies of the PGE potential of Nipissing Diabase rocks in other areas have been completed over the last few years (Conrod and Naldrett 1985; Rowell and Edgar 1984). Sampling by the author in the Cassels and Riddell area, however, has not yet yielded any significant results.

Scattered disseminated sulphides are also locally present within the lowest part of the Coleman Member (Gowganda Formation) sedimentary rocks which host minor pyrite, chalcopyrite and galena or calcite-quartz veins. This occurs particularly along the diabase contact or above Archean felsic volcanic rocks which commonly contain disseminated sulphides as encountered on the Silver Leader Mines Limited Property east of Bogie Lake and at the Goldex Mines Limited Property at Boulton Lake.

The three potential areas for finding cobalt, silver, and copperbearing veins are along the upper margin of the Nipissing Diabase sill; or in the lower part of the Coleman Member sedimentary rocks adjacent to the lower diabase contact; or in lower Coleman Member sedimentary rocks which overlie Archean sulphide-bearing felsic or mafic metavolcanics; and are stratigraphically below the lower diabase contact. Geological environments as mentioned above are analogous to the Cobalt Camp (Legun 1984), and the presence or absence of mineralized veins is structurally controlled and difficult to predict. Most of the known local veins are vertical and trend in a northeast direction. Previous prospecting and near surface drilling discovered numerous indications of mineralized veins. Higher-grade veins may be present at depth along any of the key stratigraphic horizons previously discussed.

Volcanogenic massive sulphide mineralization consisting of pyrite, pyrrhotite, and minor chalcopyrite and sphalerite typically occur as sulphide veins in hydrothermally altered, felsic volcanic flows and/or pyroclastic rocks. They possibly represent stringer zones associated with sulphide deposits not exposed or eroded.

Previous analyses from surface trenches at the New Athona Property indicate 1 to 2% Cu and less than 1% Zn, with trace amounts of Au and Ag (Assessment Files, Resident Geologist's Office, Cobalt). Subsequent diamond drilling, however, indicates decreased mineralization beneath the surface trenches. Previous work also indicates that the area underlain by Archean metavolcanics has been covered by various electromagnetic surveys and all major conductors have been drilled, all with negative results for economic base-metal mineralization. Thus, although the geological environment for massive sulphide deposits is good, the only real potential that remains is for deeper diamond drilling and subsequent down-hole geophysical surveys to establish the possible presence of deeply buried ore bodies.

No major gold occurrences have been reported in the map area, the geological environment is favourable for gold mineralization within the Archean metavolcanics in Cassels Township. These are part of the Younger Volcanic Complex (YVC) of the Temagami Greenstone Belt and include intensely carbonatized and/or silicified zones associated with the northeast-trending Link Lake deformational zone which cuts across Boot Bay.

In addition, the presence of felsic pyroclastic units with some minor sulphides, and areas of minor quartz veining and intense shearing make the Link Lake deformational zone a good target for gold exploration.

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024. Stratigraphic Mapping of the Huronian Supergroup, Southern Cobalt Embayment

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

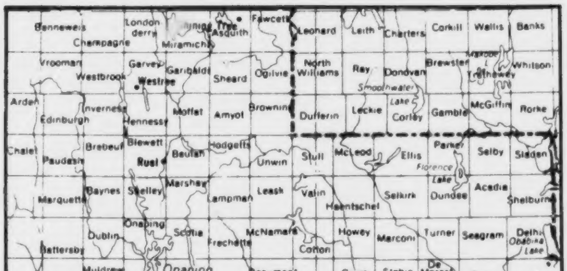
The southern Cobalt Embayment is located immediately northeast of the City of Sudbury. The study area includes McKim, Neelon, Dryden, Garson, Falconbridge, Street, Maclennan, Scadding, Davis, and Rathbun Townships. Access is provided by Highways 69 and 17, as well as municipal and regional roads. Additional access is provided by cottage roads, company roads on Falconbridge Limited property, and abandoned exploration and logging trails.

The goal of the present project is to come to a better understanding of the stratigraphy and paleoenvironment of the Huronian Supergroup in the southern Cobalt Embayment and to identify paleoenvironments that may host paleoplacer gold mineralization (Mossman and Harron 1983).

MINERAL EXPLORATION

The history of mineral exploration and mining in the Sudbury and southern Cobalt Embayment areas dates back to 1883 when a nickel-copper deposit associated with the Sudbury Igneous Complex was discovered (Pye *et al.* 1984). Early work in the areas concentrated on such deposits. The target of exploration activity shifted at the turn of the century and during the 1930s, 1950s, and 1980s to gold occurrences in quartz and quartz-carbonate veins and in chloritic breccia zones hosted by rocks of the Huronian Supergroup and Nipissing gabbros (Thomson and Card 1963; Dressler 1982). Past producers are: the Crystal Gold Mine in Rathbun Township (Dressler 1982); the Scadding Gold Mine (*see* D.R. Watts *in* Dressler 1982, p.113) in Scadding Township; and the Norstar Mine (Thomson and Card 1963) in Davis Township. The Norstar Mine is again producing at present.

During the late 1950s uranium deposits were discovered at the base of the Huronian succession southwest of Sudbury and to a minor extent also in the present area of investigations (Thomson 1960, 1961; Meyn and Matthews 1980; Dressler 1982). More recently, exploration for paleoplacer concentrations of gold and uranium in rocks of the Huronian Supergroup has been carried out (Long 1981; Long and Lloyd 1983; Sauerbrei and Phipps 1983; Long and Colvine 1985; Dressler 1986). Much of these more recent efforts were directed toward identifying paleoenvironments favourable for gold mineralization similar to major gold deposits of the Witwatersrand system in South Africa.



LOCATION MAP

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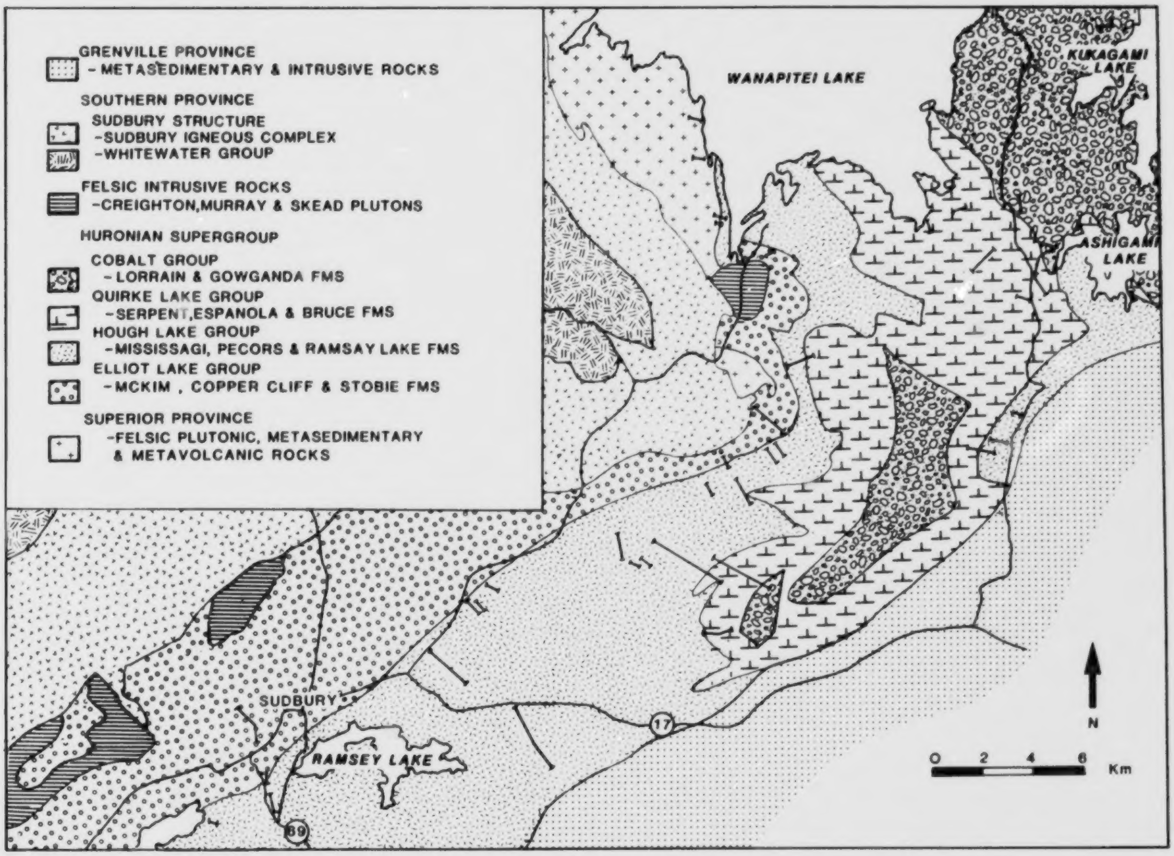
GRENVILLE PROVINCE
- METASEDIMENTARY & INTRUSIVE ROCKS
SOUTHERN PROVINCE
SUDBURY STRUCTURE
-SUDBURY IGNEOUS COMPLEX
-WHITEWATER GROUP
FELSIC INTRUSIVE ROCKS
-CREIGHTON,MURRAY & SKEAD PLUTONS
HURONIAN SUPERGROUP
COBALT GROUP
- LORRAIN & GOWGANDA FMS
QUIRKE LAKE GROUP
-SERPENT,ESPANOLA & BRUCE FMS
HOUGH LAKE GROUP
-MISSISSAGI, PECORS & RAMSAY LAKE FMS
ELLIOT LAKE GROUP
-MCKIM , COPPER CLIFF & STOBIE FMS
SUPERIOR PROVINCE
-FELSIC PLUTONIC, METASEDIMENTARY & METAVOLCANIC ROCKS
WANAPITEI LAKE
KUKAGAMI LAKE
ASHIGAMI LAKE
SUDBURY
RAMSEY LAKE
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Figure 024.1. *Simplified geological map of the southern Cobalt Embayment, showing locations of measured sections.*

GENERAL GEOLOGY

Geological mapping of the present study area has been done by a number of workers including Fairbairn (1939), Thomson (1961), Grant *et al.* (1962), Thomson and Card (1963), Innes (1978), and Dressler (1982, 1984a, in preparation).

Stratigraphic, sedimentologic, and petrographic studies of the Huronian Supergroup of the southern Cobalt Embayment and in areas adjacent to it were done by Meyn (1973), Card *et al.* (1977), Card (1978), and Dressler (1982, 1984b, 1986).

Figure 024.1 shows a simplified geological map of part of the southern Cobalt Embayment. Nipissing gabbro intrusions which occur throughout the Huronian succession have been omitted from the map. Figure 024.1 also shows the location of stratigraphic sections measured by the author and the legend of this figure may serve as a stratigraphic column for the reader unfamiliar with the Huronian stratigraphy.

Southwest of Wanapitei Lake, the Huronian succession includes, from the base upwards, rocks of the Stobie, Copper Cliff, McKim, Ramsay Lake, and Pecors Formations. Along the western shore of Wanapitei Lake, however, those formations are absent, and the Mississagi Formation unconformably overlies Archean basement. A major change in the depositional history of the Huronian Supergroup clearly takes place in the southern Cobalt Embayment.

STRATIGRAPHIC MAPPING

Existing geological maps and reports were used to select traverse lines giving as complete as possible exposure across individual formations. Areas where repetition of the section due to folding and faulting, where present, were avoided, as were areas where the section was disrupted by Nipissing gabbro intrusions. Areas where well developed Sudbury Breccia bodies were reported were also avoided. Faulting, Nipissing gabbro intrusions, Pleistocene glaciofluvial outwash deposits, and industrial and residential developments disrupt and obscure parts of the succession through much of the southern Cobalt Embayment. Uninterrupted sections across entire formations were present in only a few places.

Sedimentological features including bed thickness, rock colour and composition, grain size and shape, and post-depositional deformation were measured and recorded. Structures, including parallel- and crossbedding, ripple crosslamination, flute marks, and pebble abundance, lithology, and orientation were also measured and recorded. Stereographic projections were used to determine the direction of flow during deposition of units bearing current-generated features.

Representative samples of the rock types present in the southern Cobalt Embayment were collected. These samples have been submitted for geochemical analyses in an attempt to identify auriferous horizons in the Huronian succession.

PRELIMINARY RESULTS

Three units of the Elliot Lake Group are exposed in the area. These units are the Stobie, Copper Cliff, and McKim Formations. The Stobie Formation at the bottom of the group has a maximum exposed thickness of 1240 m and consists of massive and pillowed mafic metavolcanic flows, with scarce mafic lithic tuffs and pyroclastic breccias. The massive and pillowed metavolcanics are amygdaloidal in places. The Copper Cliff, McKim, and Ramsay Lake Formations above the Stobie all thin, and subsequently disappear between Sudbury and the southern end of Wanapitei Lake. Each formation succeeds the previous one in lying directly over the Stobie Formation. After the disappearance of the Ramsay Lake Formation, the Stobie Formation is overlain by the Mississagi Formation. Locally derived monomictic orthoconglomerate and wacke horizons are present near the top of the Stobie Formation in central Falconbridge Township. Rare lenses of polymictic orthoconglomerate, containing granitic and quartz clasts, are also present. The formation is overlain by a thin sequence of McKim Formation in this area.

The Copper Cliff Formation overlies the Stobie Formation in Garson and McKim Townships. The lower part of the Copper Cliff Formation and the contact between the Copper Cliff Formation and the underlying Stobie Formation are not exposed. The thickness of the exposed section is 300 m. The formation is made up of quartz-feldspar crystal tuff, massive to flow-banded rhyolite, and lapilli-tuff to pyroclastic breccia.

The McKim Formation overlies the Copper Cliff Formation in McKim and part of Garson Townships, and the Stobie Formation in parts of Garson and Falconbridge Townships. The contact between the Copper Cliff and McKim Formations is conformable, and gradational across about 100 m. The contact between the Stobie and McKim Formations is not exposed. The exposed section of McKim Formation is 1300 m thick in McKim Township. The formation thins, and eventually pinches out in Falconbridge Township. It consists of medium-bedded wacke and thinly bedded siltstone. A variety of sedimentary structures, characteristic of turbidites, including flute casts, graded beds, ripple crosslaminations, load casts, and flame structures are present.

All three formations of the Hough Lake Group (Figure 024.1) are present in the southern Cobalt Embayment. The Ramsay Lake Formation overlies the McKim Formation in McKim, Garson, and part of Falconbridge Townships, and overlies the Stobie Formation in part of Falconbridge Township. The contact between the Ramsay Lake and the overlying McKim Formations is sharp and conformable. The contact between the Ramsay Lake and Stobie Formation is not exposed. The exposed section of the Ramsay Lake Formation is 385 m thick in McKim Township. The formation thins, and eventually pinches out in Falconbridge Township. It consists of massive- to parallel-bedded polymictic paraconglomerate and pebbly wacke. Massive thickly bedded subarkose is present at the top of the formation in McKim Township. Cross-stratification is present in the parallel-bedded pebbly wacke, but it is not common.

The Pecors Formation overlies the Ramsay Lake Formation. The contact between the formation is conformable and in some places gradational over several metres. The maximum measured thickness of the Pecors Formation in the southern Cobalt Embayment is 280 m. The formation thins rapidly in central Falconbridge Township, and pinches out in the northern part of this township. The formation consists of thinly bedded siltstone, wacke, and quartz-feldspar arenite. Sedimentary structures characteristic of turbidites such as graded beds and ripple crosslamination are present along with planar crossbedded tabular beds characteristic of fluvial deposits.

The Mississagi Formation overlies the Pecors Formation in McKim and Neelon Townships, and overlies the Ramsay Lake Formation in Falconbridge Township. In southern Maclennan Township, it overlies the Stobie Formation, while in the northern part of this township the Mississagi Formation rests directly on Archean granitic and metasediments. The contact between the Pecors and Mississagi Formations is conformable and abrupt. The lowermost Mississagi Formation consists of massive to wave-rippled, fine- to medium-grained subarkose, which does not occur elsewhere in the formation. The lowermost Mississagi Formation includes wacke with abundant mudstone fragments, and pebbly channel lag deposits. Both of these rock types do not occur higher up in the Mississagi Formation. The contact between the Stobie and Mississagi Formations is abrupt and conformable. A coarsening upward sequence of parallel-laminated argillaceous siltstone to fine-grained wacke approximately 30 m thick, with a few discontinuous lenses of polymictic paraconglomerate immediately overlying the volcanic rocks, is present at the base of the formation. Further north, the lowermost Mississagi Formation overlying Archean basement rocks consists of discontinuous lenses of polymictic paraconglomerate in medium-grained arkose. Some of the paraconglomerate lenses bear up to 10 percent detrital pyrite. A sequence of parallel-laminated siltstone succeeds the paraconglomerate and arkose, and is in turn succeeded by arkose deposits more typical of the Mississagi Formation. The parallel-laminated siltstone in the lowermost Mississagi Formation appears to be unique to Maclennan Township. The siltstone may represent a local member within the formation, or may be correlative with one or more of the formations which pinch out to the southwest. The thickest measured section of the Mississagi Formation is in southern Falconbridge Township, where the formation is 3080 m thick. The formation appears to thin northward as the underlying units do, but poor exposure in Maclennan Township precludes confirmation of this. The formation consists mainly of thickly bedded medium- to coarse-grained, crossbedded arkose to feldspathic wacke with minor amounts of interstratified massive- to parallel-laminated siltstone and fine-grained wacke. The sedimentary structures present, such as planar crossbeds, trough crossbeds, and channel fillings, are characteristic of the deposits of shallow, sandy braided rivers (Ethridge 1980).

The three members of the Quirke Lake Group all occur within the southern Cobalt Embayment. The Bruce Formation overlies the Mississagi Formation with a sharp, conformable contact. The maximum measured thickness of the formation is 1580 m. The formation consists of massive, sparsely pebbled polymictic paraconglomerate to pebbly wacke, with interstratified massive and rarely crossbedded, fine- to medium-grained arkose. The arkose interbeds occur in the lower and middle parts of the formation, and appear to be best developed where the formation is thickest. The formation appears to thin northward rather abruptly in Falconbridge Township.

The Espanola Formation conformably overlies the Bruce Formation with a contact that is sharp to gradational over approximately 3 m. Exposure of the Espanola Formation is poor throughout the map area, but in one part of Falconbridge Township, a complete section is exposed that is about 250 m thick. The formation consists of massive, white limestone, interlaminated limestone and calcareous siltstone, parallel-laminated argillite, and parallel- and ripple-crosslaminated calcareous siltstone, siltstone to fine-grained wacke and arkose. Dessication cracks and mudstone flakes are present in the Espanola Formation in central Scadding Township. The author believes that the formation probably represents a tidal flat or lagoonal marine environment.

The Serpent Formation conformably overlies the Espanola Formation. The contact is gradational across several tens of metres of fine-grained, parallel- to ripple-crosslaminated arkose and siltstone. In Street Township, an incomplete section of Serpent Formation rocks is about 670 m thick. In Scadding Township, a complete section is 350 m thick. This may be due to the Serpent Formation, like the underlying units, thinning northward, or it may be due to differential erosion prior to deposition of the Gowganda Formation. The Serpent Formation consists of fine- to medium-grained, massive to crosslaminated, medium to thickly bedded arkose and subarkose. The author believes that the sedimentary structures present, such as crossbedding, suggest deposition was by sandy, ephemeral, braided streams.

Two members of the Cobalt Group are present in the southern Cobalt Embayment. The Gowganda Formation unconformably overlies the Serpent Formation. Where the contact is exposed in Scadding Township, cobbles of Serpent Formation sandstone are present in conglomerate in the lowermost few metres of the Gowganda Formation. Stereographic manipulation of bedding attitudes recorded at the contact further indicate that rocks of the Serpent Formation were folded into open folds, and were subsequently eroded to form a gently dipping surface prior to deposition of the Gowganda Formation. No complete section of the Gowganda Formation is present in the area studied due to erosion and the disruption of the section by faulting. The thickest section measured is 900 m thick. The Gowganda Formation consists of massive to parallel-bedded, polymictic paraconglomerate to pebbly wacke, massive to parallel-laminated siltstone to pebbly siltstone, and thinly to medium-bedded, fine- to medium-grained wacke and minor arkose. Ripple-crosslaminated and planar crossbedding are present in a few places in the arkose. Siltstone to pebbly siltstone is the predominant lithology found in the formation. The relative abundance of wacke and arkose increases near the top of the formation.

The Lorrain Formation conformably overlies the Gowganda Formation. The contact is gradational over a few metres where it is exposed in Rathbun Township. Owing to erosion, there is no complete section of the Lorrain Formation in the study area. A section across the lower part of the formation in Rathbun Township is 330 m thick. The Lorrain Formation consists of massive to medium-bedded, medium- to coarse-grained arkose, subarkose, silty micaceous arkose, and wacke. Crossbedding is rarely present. It is highlighted in places by graded foresets where the grain size is coarse, or by concentrations of hematite along the foresets where the rock is medium grained.

PALEOCURRENT MEASUREMENTS

Paleoflow data from eight of the formations present in the southern Cobalt Embayment are shown in Figure 024.2. The number of measurements from each formation is indicated at the centre of each diagram.

Data from the McKim Formation indicate that flow during deposition was generally westerly, but with a wide range of flow directions. Figure 024.3 indicates, however, that distinct differences exist between flow directions in turbidite beds of proximal and distal facies. Flow in proximal turbidites appears to have been northward and southward in McKim Township, possibly directed from the margins to the centre of a long, narrow, east-trending basin. Flow in the distal turbidites was westward, along the axis of the basin.

Paleoflow directions in the Pecors Formation are generally southwestward, rarely northeastward. The complex depositional environment (*see* section on "Preliminary Results") does not allow a reliable interpretation of directions with the limited data available.

Data from the Mississagi Formation show a well defined unimodal flow direction. This differs from the bimodal flow direction present in the formation west of Sudbury (Card 1978).

Limited data from arkose horizons in the Bruce Formation does not give any well defined paleoflow direction. Paleoflow directions in the Espanola Formation are south to southwest in the southern Cobalt Embayment.

Data from the Serpent Formation indicate paleoflow was to the northeast, with weakly developed bimodal flow directions. This flow direction is almost opposite to that of the Mississagi Formation in the southern Cobalt Embayment.

Paleoflow directions in the Gowganda Formation are strongly bimodal southerly and easterly. No ex-

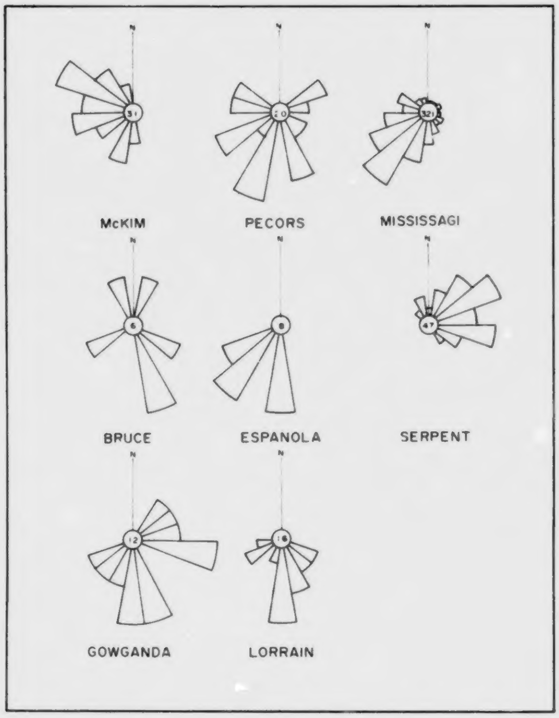

Figure 024.2. *Palaeocurrent directions in rocks of the Huronian Supergroup, southern Cobalt Embayment.*

planation for this bimodality has been determined yet.

Data from the Lorrain Formation indicate that paleoflow in the southern Cobalt Embayment was southerly, with a weakly bimodal southwesterly flow component.

ECONOMIC GEOLOGY

It is beyond the scope of the present report to describe all the mineral occurrences associated with the Huronian rocks in the sector of the southern Cobalt Embayment investigated by the author in the Summer of 1986. The aim of the project is to relate the sedimentology of the metasedimentary units studied to their potential for paleoplacer deposits. Many samples have been collected for chemical analyses. Analytical results, however, have not been received yet and therefore, it is premature to speculate on the mineral potential of the rocks investigated. It is expected, though, that some samples being analyzed will show higher than background concentrations of gold. The author believes that pyritic, polymictic orthoconglomerates at and near the base of the Mississagi Formation in Maclennan and Falconbridge Townships, and polymictic orthoconglomerate in the uppermost Stobie Formation in Maclennan and Falconbridge Townships, hold the greatest potential for placer concentrations of gold.

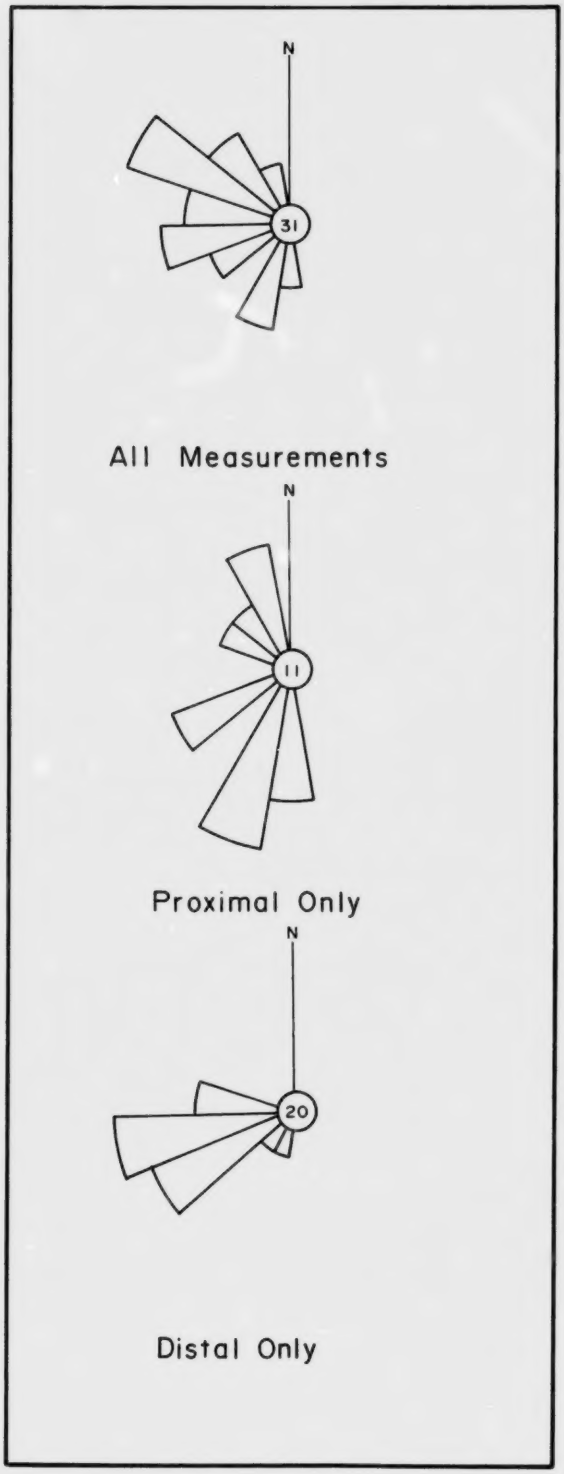

Figure 024.3. *Paleocurrent directions in proximal and distal turbidites in the McKim Formation, McKim Township.*

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025. Footwall Breccia and Breccias of the Onaping Formation in Dowling, Levack, and Morgan Townships, District of Sudbury

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INTRODUCTION

The area of investigation is located south and north of the Sudbury Igneous Complex in Dowling, Levack, and Morgan Townships. It forms part of an area mapped by Lafleur and Dressler (1985) and Muir (1983) and is easily accessible via Highway 144 from Sudbury, a regional road to the Town of Levack, and several mining roads.

The field work undertaken in 1986 forms part of the third year of a program of scientific cooperation between the Ontario Geological Survey and the Research Group "Earth-Moon-System" of the University of Muenster, Federal Republic of Germany. The investigations are in partial fulfillment of the requirements for the Ph.D. degree at this university.

MINERAL EXPLORATION

The Footwall Breccia bodies along the North Range of the Sudbury Igneous Complex host several large economic nickel-copper sulphide bodies (Lafleur and Dressler 1985). The breccias and the sulphides have been described in many publications, the most recent ones are in the Ontario Geological Survey Special Volume 1 "The Geology and Ore Deposits of the Sudbury Structure" (Pye *et al.* 1984). Several chapters in this volume deal with the geology of the area investigated this summer (for example, Dressler (1984) and Muir and Peredery (1984)). The reader is referred to these publications for a detailed account of the economic and general geology of the area.

FIELD INVESTIGATIONS

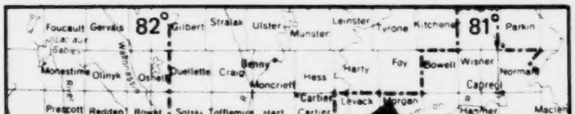
The Onaping Formation at the base of the Whitewater Group in the Sudbury Basin is subdivided into three breccia members which are from bottom to top, the Basal, Gray, and Black Members. "Melt Bodies" occur mainly in the Gray Member. These rock units are either of meteorite impact or endogenic volcanic origin and have been described by Muir and Peredery (1984). Based on this 1984 regional study, the authors of the present summary report will make an attempt to petrographically and geochemically characterize a well defined, relatively small, section of the Onaping Formation in the North Range of the Sudbury Structure.

During the 1986 field work, the authors continued detailed investigations started in 1985.

STUDY OF THE BASAL MEMBER OF THE ONAPING FORMATION AND THE FOOTWALL BRECCIA

R. Lakomy completed detailed mapping and sampling of the Footwall Breccia occurrences and the transition into the footwall rocks across the megabreccia zone (Pattison 1979) .This study was initiated in 1985 (Brockmeyer and Lakomy 1985). Footwall Breccia dikes were observed that intrude the footwall rocks. The megabreccia forms a transition zone 10 to 30 m thick in which large (commonly >5 m in size) parautochthonous footwall rock fragments are embedded in Footwall Breccia matrix. This matrix may make up a few percent to approximately 30 percent of the megabreccia and commonly contains granophyric material. All large fragments are of local derivation.

An attempt was made to statistically characterize the fragment population of the Footwall Breccia and



LOCATION MAP

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compare it with the fragment population of the Basal Member of the Onaping Formation which is separated from the Footwall Breccia by the Sudbury Igneous Complex. Obvious differences include the relative abundance of mafic fragments in the Footwall Breccia and the scarcity of these fragments in the Basal Member. These differences make it difficult to suggest that all the breccias originally belonged to one breccia accumulation that was split apart by the Sudbury Igneous Complex.

Chemical investigations were begun in 1985, and several more specimens were selected this year for further study. Preliminary results from whole rock and trace element analyses appear to indicate that the matrix of the breccias of the Basal Member is chaotic in chemical composition. The investigations undertaken this year and statistical treatment of the results are intended to substantiate the 1985 results.

BRECCIAS OF THE GRAY AND BLACK MEMBERS AND THE MELT BODIES OF THE ONAPING FORMATION OF THE NORTH RANGE

Peter Brockmeyer continued his detailed investigations and sampling of well exposed breccia occurrences in Levack and Morgan Townships. An attempt has been made to statistically characterize the fragment population in an almost complete section across the upper two members of the Onaping Formation and compare it with field and chemical characteristics of the breccia matrices. The chemical investigations are presently under way.

During the recent field work, several observations made in 1985 by Brockmeyer and Lakomy (1985), and previously made by other workers, could be substantiated. A dike, approximately 30 cm thick and a few metres long, of "fluidal glass" (Peredery 1972) and a sharp, discontinuous contact between the Basal Member and the Gray Member were observed. Multiple brecciation and other discontinuous sharp contacts within the breccia deposits were also observed (Muir and Peredery 1984; Brockmeyer and Lakomy 1985).

The results of the authors' field and laboratory investigations hopefully will lead to a better understanding of the origin of the Sudbury Structure. The authors gratefully acknowledge the assistance obtained from the management and geological staff of Falconbridge Limited and Inco Limited.

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026. Contact Metamorphism of the Footwall Rocks and Sudbury Breccias in Levack and Cartier Townships, District of Sudbury

M.E. Avermann and V. Mueller-Mohr

Graduate Students, University of Muenster, Federal Republic of Germany

INTRODUCTION

The area of investigation is located in Levack and Cartier Townships, north of the Sudbury Igneous Complex. It forms part of an area previously mapped by Lafleur and Dressler (1985) and is accessible via Highway 144 from the City of Sudbury, a regional road to the Town of Levack, and several mining roads.

This project forms part of the third year of scientific cooperation between the Ontario Geological Survey and the Research Group "Earth-Moon-System" of the University of Muenster, Federal Republic of Germany. The investigations are in partial fulfillment of the requirements for M.Sc. geology degrees at the University of Muenster.

MINERAL EXPLORATION

It is beyond the scope of this report to describe the mineral exploration and mining activity carried out in the area of investigation. Several past and present producers are located in Levack Township, and the reader is referred to a recent publication titled, "The Geology and Ore Deposits of the Sudbury Structure" (Pye *et al.* 1984). In this publication several of the Levack Township mines are described in detail. Lafleur and Dressler (1985) give an account of the mining and mineral exploration activities in Levack and neighbouring townships.

FIELD INVESTIGATIONS

The authors mapped two adjacent 3 by 3 km areas in detail west of the Fecunis Lake Fault and north of the Sudbury Igneous Complex in Levack and Cartier Townships. Emphasis was placed on:

STUDY OF THE SUDBURY BRECCIA

by V. Mueller-Mohr

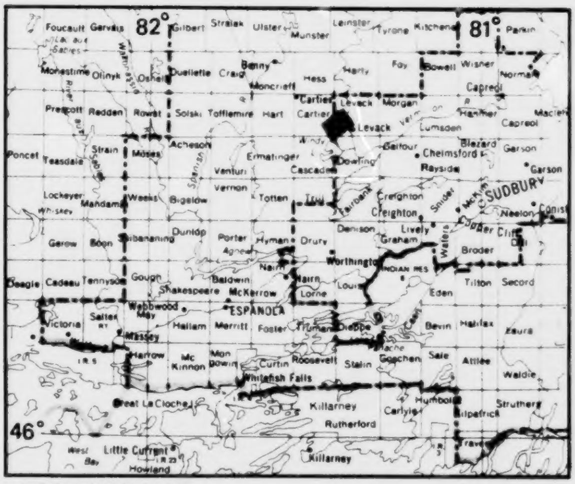
The Sudbury Breccias are interpreted as pseudotachylites occurring in rocks older than the Sudbury Igneous Complex. These breccias have been studied on a regional basis by several workers (e.g. Dressler 1984).

The breccias from a small area near the contact with the Sudbury Igneous Complex will be petrographically compared with breccia bodies exposed along Highway 144 northwest of the Sudbury Igneous Complex. Along this highway, Sudbury Breccias occur up to 60 to 70 km away from the Complex. Many samples were taken from exposures along the highway and in the detailed study area near the Sudbury Igneous Complex for petrographic and geochemical investigations and for comparison with breccias from meteorite impact structures studied by the Research Group "Earth-Moon-System" of the University of Muenster.

STUDY OF CONTACT METAMORPHISM OF THE FOOTWALL ROCKS

by M.E. Avermann

The footwall rocks, including the Footwall Breccia and the Sudbury Breccia bodies, were subjected to contact metamorphism adjacent to the Sudbury Igneous Complex. The zone of contact metamorphic overprint is as much as approximately 1.2 km wide and, according to Dressler (1984), can be subdivided into three subzones; a pyroxene hornfels facies, a hornblende hornfels facies, and a subzone characterized by plagioclase and quartz recrystallization only.


82°
81°
46°
Foucault
Gervais
Gilbert
Straiak
Ulster
Munster
Leinster
Tyrone
Kitchener
Parkin
Lac aux Sables
Mohestime
Olinyk
Oshell
Ouellette
Craig
Benny
Moncrieff
Hess
Hanly
Foy
Bowell
Wisner
Norman
Capreol
Cartier
Levack
Morgan
Prescott
Redden
Rowat
Solski
Tofflemire
Hart
Hanmer
Maclennan
Lumsden
Acheson
Windy
Balfour
Blezard
Chelmsford
Garson
Poncet
Teasdale
Strain
Moses
Ermatinger
Venturi
Cascade
Dowling
Rayside
Lockeyer
Whiskey
Mandamin
Weeks
Bigelow
Vernon
Totten
Trill
Fairbank
Creighton
Snider
McKim
SUDBURY
Neelon
Gerow
Boon
Sibananing
Dunlop
Porter
Agnew
Hyman
Drury
Denison
Lively
Graham
Waters
Copper Cliff
Broder
Dill
Worthington
INDIAN RES
Nairn
Beagle
Cadeau
Tennyson
Gough
Baldwin
Shakespeare
McKerrow
Louise
Lorne
Tilton
Secord
Eden
Victoria
Salter
Webbwood
May
ESPANOLA
Hallam
Merritt
Foster
Truman
Dieppe
Bevin
Halifax
Laura
Massey
Harrow
Mc Kinnon
Mongowin
Curtin
Roosevelt
Stalin
Goschen
Sale
Attlee
Waldie
Whitefish Falls
Great La Cloche
Killarney
Carlyle
Humboldt
Kilpatrick
Struthers
Rutherford
West Bay
Little Current
Howland
I.R. 5
I.R. 23

LOCATION MAP

Scale : 1 : 1 584 000
or 1 inch to 25 miles

During the field work, many rock specimens were taken for detailed petrographic investigations. Of special interest will be the distinction between Archean regional high rank metamorphism, the Proterozoic contact metamorphic overprint related to the intrusion of the Sudbury Igneous Complex, and a later retrograde metamorphism.

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Pye, E.G., Naldrett, A.J., and Giblin, P.E. (eds.)
1984: The Geology and Ore Deposits of the Sudbury Structure; Ontario Geological Survey, Special Volume 1, 603p. Accompanied by Map 2491, scale 1:50 000, Map NL-16/17-AM Sudbury, scale 1:1 000 000, and 3 charts.

027. Falconbridge Township, District of Sudbury

B.O. Dressler

Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto

INTRODUCTION

Falconbridge Township is located approximately 15 km northeast of the City of Sudbury. It is easily accessible from Sudbury via a local road to the Town of Falconbridge and several private mining roads.

MINERAL EXPLORATION

Mineral exploration in Falconbridge Township dates back to the late 1890s. The Falconbridge nickel-copper deposit was discovered by Thomas Edison in 1899. In 1916 the Longyear Company outlined part of the ore body. In 1928 the property was sold to Ventures Limited and in 1929 the mine was brought into production by Falconbridge Nickel Mines Limited (presently Falconbridge Limited; Owen and Coats 1984). Mining ceased in 1985 due to a rock burst. The nickel-copper deposit of the Falconbridge East Mine, the only presently producing mine in the area, was discovered and outlined by diamond drilling in 1916 by the Longyear Company. Falconbridge Nickel Mines Limited started production in 1951. The nickel-copper deposit of the Norduna Mine, formerly owned by Norduna Mines Limited, produced from 1957 to 1962. The property is presently owned by Falconbridge Limited (Peter Snajdr, Senior Staff Geologist, Falconbridge Limited, personal communication, 1986).

Limited development work occurred at the Falcon Gold Mine in central Falconbridge Township in the late 1930s. The property is presently owned by Falconbridge Limited.

Many small mineral occurrences exist in Falconbridge Township south of the Falconbridge, Falconbridge East, and Norduna Mines and have been explored by several exploration companies and prospectors using diamond drilling and geological and geophysical methods. The exploration efforts were not successful in delineating any significant mineral deposit. The reader is referred to Dressler (in preparation) for a summary of assessment work.

GENERAL GEOLOGY

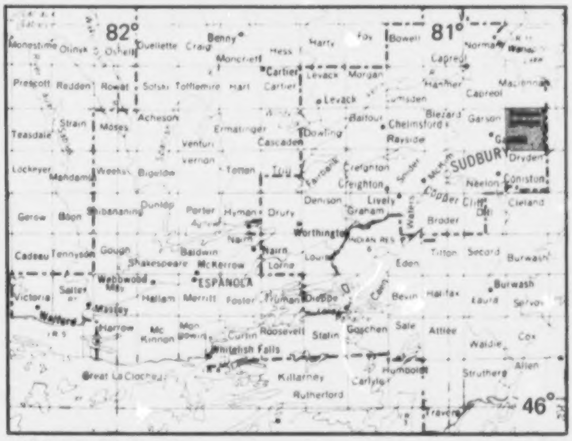
Granitic rocks and anorthosite of Archean age occur in the north-central sector of the township. These rocks are intruded by Archean or Early Proterozoic diabase dikes.

Rocks of the Proterozoic Huronian Supergroup overlie the Archean rocks. Mafic metavolcanics, minor rhyolites, and intercalated minor wackes and orthoconglomerates of the Stobie Formation occur at the base of the Huronian succession and are overlain by orthoconglomerates, paraconglomerates, and pebbly wackes of the Ramsay Lake Formation.

Thickly bedded arenites and minor intercalated wackes of the Missassagi Formation are well exposed and form several prominent ridges all across the township from the abandoned nickel-iron refinery of Falconbridge Limited to northern Falconbridge Township (Figure 027.1). Sedimentary features such as planar crossbeds, trough crossbeds, and channel fillings suggest a fluviatile depositional environment for the formation.

Orthoconglomerates, paraconglomerates, pebbly wackes, and arkoses of the Bruce Formation overlie the Mississagi Formation. The formation is possibly glacial in origin as has been suggested also for two other formations (Ramsay Lake and Gowganda Formations) by Coleman (1905a, 1905b), Casshyap (1969, 1971), Young (1970), and Lindsey (1971). It is very thick (Debicki, this volume) west of a thick olivine diabase dike in western Falconbridge Township and much thinner east of the dike (Figure 027.1).

The Espanola Formation overlying the Bruce Formation is a sequence of laminated wackes, limestone, and thinly bedded, intercalated fine-


82°
81°
46°
SUDBURY
ESPANOLA
Falconbridge
Capreol
Levack
Chelmsford
Rayside
Dowling
Cascaden
Creighton
Lively
Graham
Copper Cliff
Coniston
Nickel Centre
Dryden
Garson
Blezard
Broder
Walden
Worthington
Drury
Nairn
Louise
Webbwood
Massey
Whitefish Falls
Killarney
Great La Cloche
Eden
Tilton
Secord
Burwash
Humboldt
Struthers
Allen
Cox
Waldie
Attlee
Sale
Goschen
Roosevelt
Curtin
Dieppe
Truman
Foster
Merritt
Hallam
McKerrow
Baldwin
Shakespeare
Gough
Tennyson
Porter
Hyman
Dunlop
Shibananing
Bigwood
Venturi
Ermatinger
Acheson
Moses
Strain
Teasdale
Lockeyer
Mandamin
Gerow
Boon
Cadeau
Tyson
Victoria
Salter
May
Prescott
Reaiden
Rowat
Solski
Totten
Trill
Hart
Cartier
Moncrieff
Hess
Harty
Fox
Bowell
Norman
Hanmer
Morgan
Balfour
Benny
Craig
Ouellette
Olinyk
Onaping
Cleland
Dill
Halifax
Laura
Bevin
Carlyle
Rutherford
Travers

LOCATION MAP

Scale : 1 : 1 584 000
or 1 inch to 25 miles

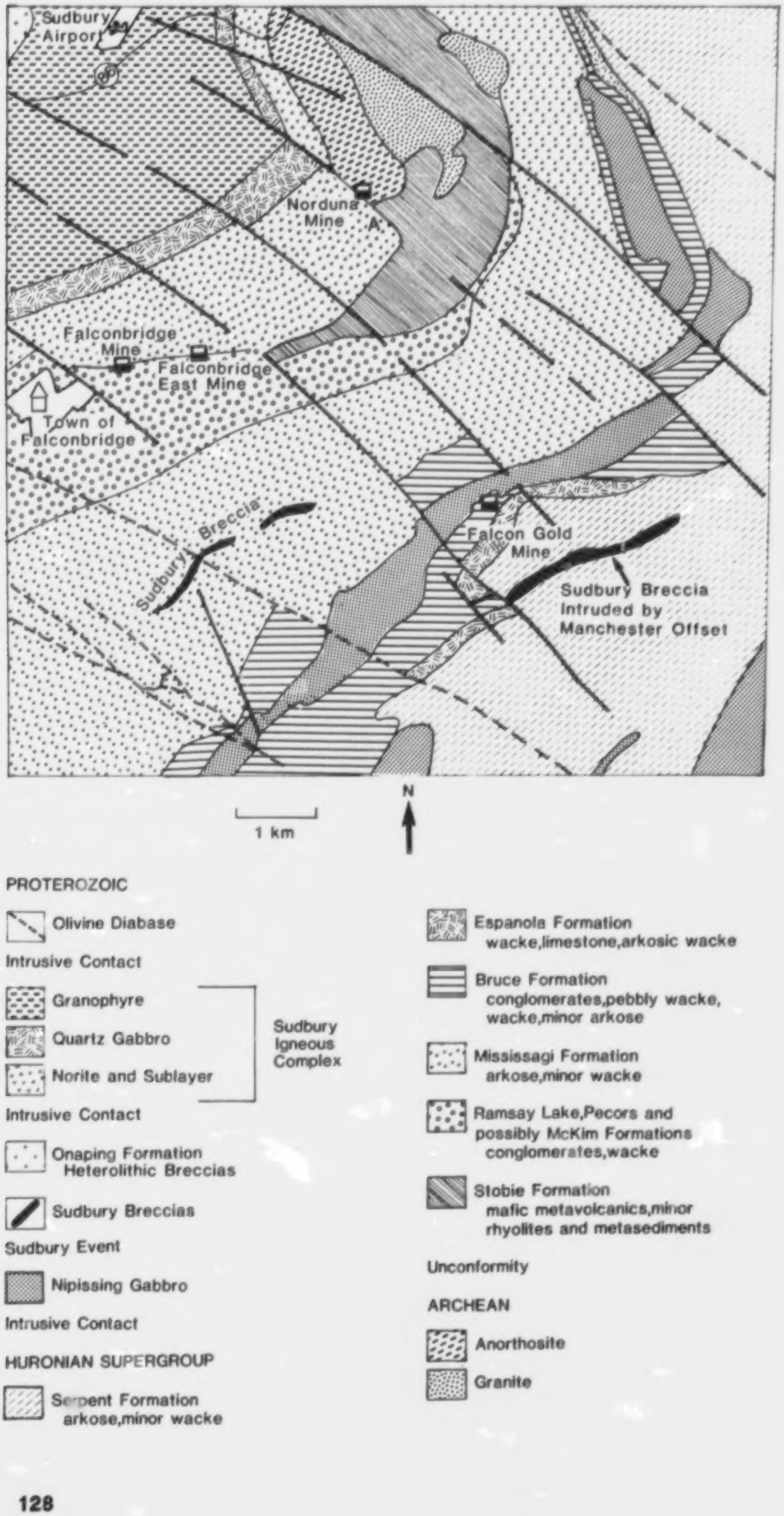

Sudbury Airport
Norduna Mine
A
Falconbridge Mine
Falconbridge East Mine
Town of Falconbridge
Sudbury Breccia
Falcon Gold Mine
Sudbury Breccia intruded by Manchester Offset
1 km
N
PROTEROZOIC
Olivine Diabase
Intrusive Contact
Granophyre
Quartz Gabbro
Norite and Sublayer
Sudbury Igneous Complex
Intrusive Contact
Onaping Formation Heterolithic Breccias
Sudbury Breccias
Sudbury Event
Nipissing Gabbro
Intrusive Contact
HURONIAN SUPERGROUP
Serpent Formation arkose,minor wacke
Espanola Formation wacke,limestone,arkosic wacke
Bruce Formation conglomerates,pebbly wacke, wacke,minor arkose
Mississagi Formation arkose,minor wacke
Ramsay Lake,Pecors and possibly McKim Formations conglomerates,wacke
Stobie Formation mafic metavolcanics,minor rhyolites and metasediments
Unconformity
ARCHEAN
Anorthosite
Granite

Figure 027.1. *Geology of Falconbridge Township, District of Sudbury.*

grained arkosic wacke and wacke. The formation is not well exposed. In one place in central Falconbridge Township a thinly laminated limestone is exposed. The lamination is suggestive of algal mats. Hofmann *et al.* (1980) describe stromatolites in the formation. This, the observation of interpreted algal mats, and the fine-grained, thinly bedded sediments indicate stable depositional conditions, possible tidal flats, or lagoonal environments.

Arenites and minor wackes of the Serpent Formation are similar to the rocks of the Mississagi Formation and form the top of the Huronian succession in Falconbridge Township. These rocks are probably fluviatile in origin as they exhibit a combination of fluviatile sedimentary structures such as planar crossbeds, trough crossbeds, and channel fillings.

Nipissing gabbro forms several prominent ridges in the area. The gabbros are commonly medium grained; pegmatoid phases are scarce. Quartz veins containing minor pyrite and scarce chalcopyrite mineralization are associated with the gabbros in several places (Dressler, in preparation).

Heterolithic breccias of the Onaping Formation at the base of the Whitewater Group were encountered by diamond drilling (Assessment Files Research Office, Ontario Geological Survey, Toronto) in the very northwestern corner of the township. These breccias, and several occurrences of Sudbury Breccia in the Huronian rocks and Nipissing gabbros, are related to the origin of the Sudbury Structure (i.e. meteorite impact or endogenic, volcanic explosion; *see* Muir 1984; Peredery and Morrison 1984).

The rocks of the Onaping Formation are underlain by, from top to bottom, the granophyre, quartz gabbro, norite, and Sublayer of the Sudbury Igneous Complex. The nickel-copper deposits of Falconbridge Township are associated with the Sublayer, an inclusion-bearing gabbro to quartz diorite, the youngest phase of the Sudbury Igneous Complex. The Sublayer occurs at the base of the Igneous Complex and also forms the Manchester Offset in the southeastern part of the township.

Several olivine diabase dikes trend in a northwesterly direction across the township. These dikes represent the youngest Precambrian rocks of the area.

STRUCTURE

The structure of Falconbridge Township is characterized by several northwesterly trending faults that have affected most rock units. These units, in general, strike northeasterly to northerly and wrap around the southeastern corner of the Sudbury Igneous Complex.

Granitic rocks and anorthosites in the north central part of the township are deformed cataclastically. No obvious foliation has been observed by the author in these rocks. The metavolcanics and metasediments of the Huronian Supergroup and Nipissing Gabbros do not exhibit any penetrative, ductile deformation. Brecciation (Sudbury Breccias), small scale and medium scale block faulting and shearing and brecciation in close vicinity to major faults are common. Shatter cones are common and are best developed in arkoses.

In general, the rocks of the Huronian Supergroup form a southeasterly dipping monocline. Near the Sudbury Igneous Complex, the westernmost part of this monocline dips steeply to vertically and, in places, the rocks are overturned. Towards the east and southeast the dips flatten.

The Manchester Offset (Figure 027.1) intrudes a large northeasterly trending Sudbury Breccia dike.

The granophyre of the Sudbury Igneous Complex exhibits a very strong, penetrative, northwest-trending ductile deformation whereas the quartz gabbro, norite, and Sublayer are slightly deformed to undeformed. The undeformed, northwest-trending intrusive contact of the norite with the metavolcanic footwall rocks (A in Figure 027.1) is parallel to the schistosity in the granophyre and parallel to the major faults in the area. These observations suggest that the granophyre may be older than the norite and the quartz gabbro and that these rocks may have been emplaced after a major deformational event that deformed the Sudbury Structure including the granophyre. This interpretation is in contrast to geochronological investigations by Gibbins and McNutt (1975) and Krogh *et al.* (1984). The first authors reported a Rb-Sr whole rock age of 1680±30 Ma for the granophyre and an age of 1956±98 Ma for the norite. Krogh *et al.* (1984) reported precise U-Pb zircon and baddeleyite ages according to which the norite is 1850±1 Ma old, the granophyre 1850.5±3 Ma. Further geochronological and structural studies are needed to come to a better understanding of the timing of the major tectonic and magmatic events in the Sudbury area and to explain the obvious contradictions between the geochronological data and the field observations of the author.

ECONOMIC GEOLOGY

All producing and past producing mines in Falconbridge Township are associated with the Sublayer of the Sudbury Igneous Complex and have been described in detail by Thomson (1959) and Owen and Coats (1984).

The Falcon Gold Mine is associated with quartz veining and talc-actinolite alteration of rocks of the Bruce Formation close to a contact with Nipissing gabbro. It has been described by Phemister (1939).

Many quartz veins associated with Nipissing gabbro contain minor amounts of sulphide mineralization. Pyrite and pyrrhotite disseminations were observed in Nipissing gabbro at several locations in the area.

Gossans are common on outcrops of conglomerates of the Bruce Formation and in several places the arkoses of the Serpent Formation exhibit a rusty stain due to the presence of minor amounts of sulphide mineralization.

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028. Whitestone Lake Area, District of Parry Sound

E.G. Bright

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Regional and Economic Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

The Whitestone Lake map area is located 225 km north-northwest of the City of Toronto and includes parts of Croft, Ferrie, Hagerman, and McKenzie Townships. The map area covers about 270 km^2 and is bounded by Longitudes 79°45'W and 80°00'W, and by Latitudes 45°37'30"N and 45°45'"N. The southwestern corner of the map area lies 33 km north of the Town of Parry Sound. Access is provided by Highway 124 which traverses the south-central and eastern parts of the map area, and Highway 520 which traverses the west-central part of the map area. Access to the northwestern and northeastern parts of the map area is by canoe or float-equipped aircraft.

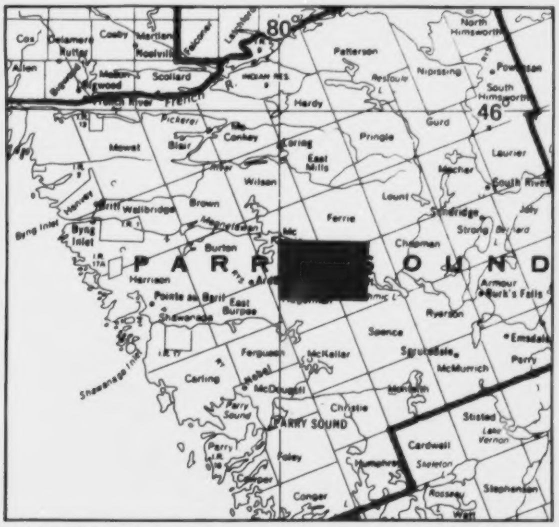
MINERAL EXPLORATION

No information on mineral exploration in the area is on record in the Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO), despite considerable prospecting work (Satterly 1943, 1956) and some recorded exploration work (AFRO) in adjacent areas, particularly to the northeast of the map area. Since the turn of the century, exploration in these adjacent areas has focused on deposits of iron, base metals, mica, feldspar, rare earth elements, radioactive minerals, and high quality lime from marbles.

GENERAL GEOLOGY

A simplified map of the Whitestone Lake area, showing the major tectonic subdivisions and geology, is presented in Figure 028.1. The area is underlain by Precambrian rocks of Middle Proterozoic age which form part of the Central Gneiss Belt (CGB) of the southwestern Grenville Province (Wynne-Edwards 1972). Recent reconnaissance mapping within and near the map area (Davidson and Morgan 1981; Davidson *et al.* 1982; Culshaw *et al.* 1983) indicated that this part of the CGB is composed of a number of lithotectonic terrains (domains and subdomains), each having distinctive lithologies, structural styles, and metamorphism. These distinctive lithologies, structural styles, and metamorphism are truncated at terrain boundaries. The boundaries are sites of high strain tectonites formed through repeated northwesterly directed ductile thrusting of one terrain over the other during the Grenville Orogeny.

The Precambrian rocks in the map area (Figure 028.1, Table 028.1) occur in three major lithotectonic terrains which, from west to east, are: Britt Domain, Parry Sound Domain, and Ahmic Domain or Subdomain (Davidson *et al.* 1982). High strain tectonites occurring mainly within Parry Sound Domain (Figure 028.1) form an easterly dipping boundary zone between this domain and the adjacent Britt Domain to the west. Likewise, high strain tectonites form a similar but westerly dipping boundary zone to the east with Ahmic Domain. This boundary zone (both western and eastern parts) has been termed by the author the Parry Sound Domain Boundary Zone (PSDBZ). The main lithologies within the three principal do-


80°
46°
North Himsworth
Patterson
Nipissing
Restoule
Powassan
South Himsworth
Hardy
Gurd
Pringle
Laurier
Machar
South River
Lount
Joly
Sundridge
Strong
Bernard
Ferrie
Chapman
Armour
Burk's Falls
Ryerson
Emsdale
Spence
Sprucedale
McMurrich
Perry
McKellar
Christie
PARRY SOUND
Stisted
Lake Vernon
Cardwell
Stephenson
Rosseau
Watt
Conger
Foley
Cowper
Carling
McDougall
Ferguson
Mowat
Blair
Conkey
Loring
East Mills
Wilson
Brown
Wallbridge
Britt
Byng Inlet
Burton
Harrison
Pointe au Baril
East Burpee
Shawanaga
Shawanaga Inlet
Pickerel
French River
French
Scollard
Cosby
Martland
Hoskin
Delamere
Allen
Falconer
Mattawan
INDIAN RES.
P A R R Y S O U N D

LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

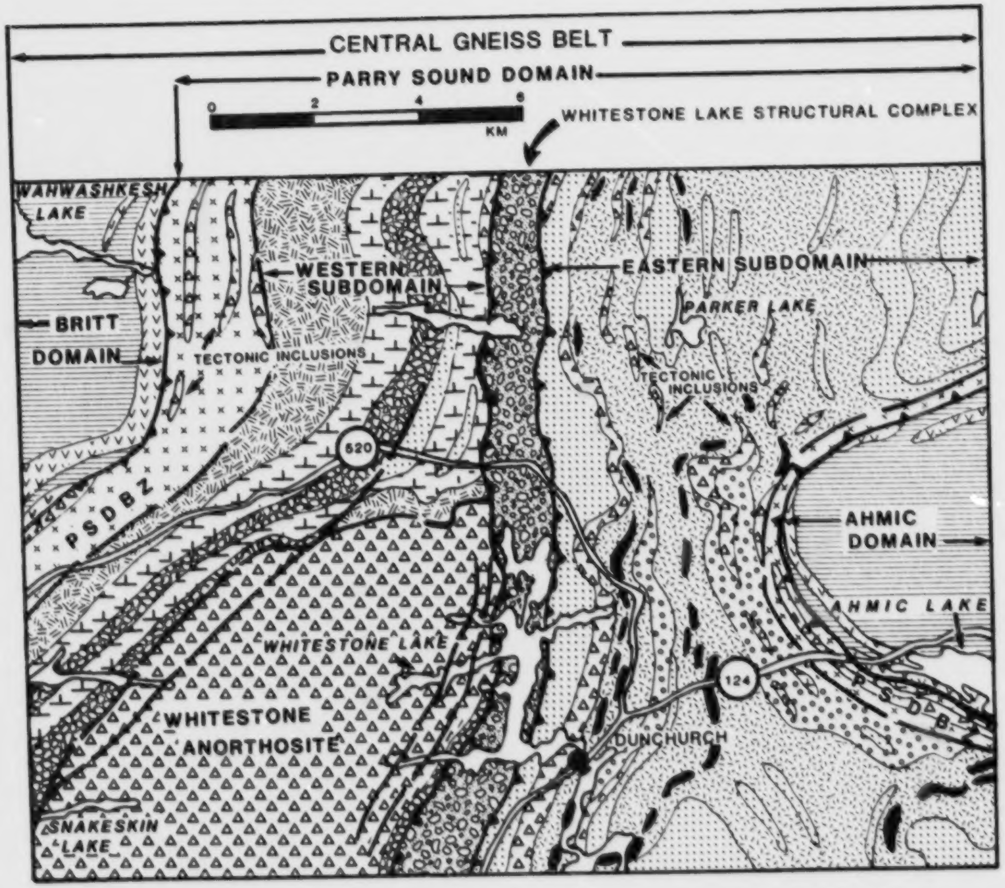

CENTRAL GNEISS BELT
PARRY SOUND DOMAIN
0
2
4
6
KM
WHITESTONE LAKE STRUCTURAL COMPLEX
WAHWASHKESH LAKE
BRITT DOMAIN
WESTERN SUBDOMAIN
TECTONIC INCLUSIONS
PSDBZ
520
EASTERN SUBDOMAIN
PARKER LAKE
TECTONIC INCLUSIONS
AHMIC DOMAIN
AHMIC LAKE
WHITESTONE LAKE
WHITESTONE ANORTHOSITE
124
DUNCHURCH
PSDB
SNAKESKIN LAKE

Figure 028.1. General geology map of the Whitestone Lake Area, Parry Sound, Ontario.

TABLE 028.1: LITHOLOGIC UNITS FOR FIGURE 028.1

MIDDLE PROTEROZOIC

GRENVILLE PROVINCE – CENTRAL GNEISS BELT

BRITT AND AHMIC DOMAINS[a]

☐ layered , migmatitic quartzofeldspathic gneiss
▨ granitic orthogneiss

PARRY SOUND DOMAIN (PSD)

PARRY SOUND DOMAIN BOUNDARY ZONE (PSDBZ)[b]
(highly disrupted lithologies)

▨ gneisses and tectonites[c]

WESTERN SUBDOMAIN
(moderatly to highly disrupted lithologies)

▨ interlayered mafic and felsic gneisses[c]
▨ mafic orthogneisses
▨ siliceous clastic metasedimentary gneisses

WHITESTONE LAKE STRUCTURAL COMPLEX

▨ marble tectonic block breccia

EASTERN SUBDOMAIN
(moderatly to highly disrupted lithologies)

▨ intermediate to mafic orthogneiss
▨ discontinous marble tectonic units
☐ quartzofeldsprthic para –and orthogneisses

YOUNGER MAFIC TO INTERMEDIATE METAPLUTONIC ROCKS

▨ ANORTHOSITE SUITE
– derived gneisses and tectonic inclusions

▨ INTERMEDIATE TO MAFIC INTRUSIVE ROCKS
– derived gneisses and tectonic inclusions

NOTES :

(a) The age relationship between the domains is uncertain

(b) The western and eastern PSDBZ may not have developed at the same time

(c) Protolith indeterminate

mains are discussed below. The order of presentation does not imply age relationships since most contacts are tectonic.

BRITT AND AHMIC DOMAINS

Rocks of the Britt Domain of the present area are almost indistinguishable from those of the Ahmic Domain and, therefore, are discussed together. Because of this lithological similarity, and the fact that the Ahmic Domain dips 50° to 80°W beneath Parry Sound Domain, Davidson and his coworkers suggest that the Ahmic is a subdomain of the 25° to 60° easterly dipping Britt Domain, and that the two might connect beneath the Parry Sound Domain (Davidson *et al.* 1982).

In the map area, Britt and Ahmic Domains are characterized by a series of foliated, layered, interlayered, and in places migmatitic, fine- to medium-grained, pink and grey quartzo-feldspathic gneisses containing variable amounts of (usually less than 10 percent combined) biotite and/or hornblende and/or magnetite. Minor interlayers of boudinaged mafic orthogneiss and mafic to intermediate gneiss are locally present in these quartzo-feldspathic gneisses which, the author believes, are derived in part at least from sedimentary rocks.

Pink granitic to granodioritic orthogneiss is confined to the margins of the Britt and Ahmic Domains. They represent deformed, flattened plutons that intruded the quartzo-feldspathic gneisses of supracrustal origin. The medium- to coarse-grained orthogneisses are characterized by flattened, elongated quartz grains and a general grain size reduction toward their contacts with the PSDBZ.

PARRY SOUND DOMAIN

Parry Sound Domain underlies more than 75 percent of the map area. It is a terrain bounded by ductile shear zones (PSDBZ) and in general is characterized by: a) highly deformed and disrupted gneisses and tectonites of supracrustal and plutonic origin; b) quartzo-feldspathic and carbonate-rich supracrustal gneisses; and c) an abundance of mafic to intermediate orthogneisses.

Two subdomains, a Western and Eastern Subdomain, have been identified by the author within the Parry Sound Domain, each characterized by its own lithological assemblage and structural pattern. They are bounded by either the western or eastern part of the PSDBZ and are separated from each other by the Whitestone Lake Structural Complex (Figure 028.1).

Parry Sound Domain Boundary Zone (PSDBZ)

Both the western and eastern parts of the PSDBZ are characterized by tectonically disrupted, fine- to medium-grained mafic to felsic gneisses of undetermined protolith. The quartz-rich, gneissic tectonites have a pronounced southeast-plunging stretching lineation. The well layered gneissic tectonites which, in places, are interlayered on a decimetric scale include, in order of decreasing abundance, the following tectonic rock types (terminology after Davidson *et al.* 1982; Hanmer and Ciesielski 1984):

1. Irregular Layered Gneiss which consists of variably sized, layered, units of amphibolite, amphibolite gneiss, and/or interlayered quartzo-feldspathic gneiss containing 10 to 25 percent centimetre-thick, discontinuous, boudinaged, locally strongly disaggregated layers of granite and granite pegmatite.
2. Porphyroclastic Gneiss which consists of relatively homogeneous, in places interlayered, gneisses of mafic, quartzo-feldspathic, and/or pelitic composition that contain isolated K-feldspar and plagioclase clasts, and feldspar or quartz-feldspar aggregates aligned parallel to the foliation (disaggregated granite pegmatite relicts).
3. Straight Gneiss, which consists of continuous, centimetre-thick layers of leucocratic granitoid and amphibolite gneiss with layers of more intermediate composition.

Western Subdomain

The Western Subdomain of the Parry Sound Domain is characterized by a high proportion of disrupted mafic orthogneiss and mafic gneiss of undetermined protolith. Quartzo-feldspathic, metasedimentary gneiss and granitoid gneisses are interlayered with the mafic gneisses but form less than 30 percent of the assemblage. Amphibolite facies rocks predominate in this subdomain. The most common type of mafic orthogneiss is porphyroblastic garnet, and plagioclase-rimmed garnet amphibolite that grades rapidly into plagioclase-streaked amphibolite gneiss within and near anastomosing shears. The metasedimentary gneisses are mainly interlayered feldspathic meta-arenite and metaquartz-arenite, and in places contain mylonitic zones.

In the southeastern part of this subdomain is the northeastern part of the large Whitestone Anorthosite body. Its intrusive contact with the gneisses of the Western Subdomain is tectonically reworked. The eastern margin of the Western Subdomain, as well as parts of the eastern margin of the Whitestone Anorthosite, are truncated by the Whitestone Lake Structural Complex (Figure 028.1).

WHITESTONE LAKE STRUCTURAL COMPLEX

The Whitestone Lake Structural Complex is a thrust fault-bounded marble tectonic block breccia zone that separates the Western and Eastern Subdomains of the Parry Sound Domain. It consists of a chaotic melange (marble tectonic breccia) of supracrustal and metaplutonic layers, lenses, and large blocks set in a marble matrix. Some of the larger isolated lenses and blocks range in size up to 300 m long and 100 m wide. Tectonic inclusions derived from the Eastern Subdomain predominate; however, lenses and large blocks of porphyroblastic garnet amphibolite, a common rock type in the Western Subdomain, were observed near the western margin of the complex. Tectonic inclusions of gabbroic meta-anorthosite are also present but are not shown on Figure 028.1.

Eastern Subdomain

The Eastern Subdomain of the Parry Sound Domain is characterized by an abundance of quartzo-feldspathic and carbonate-rich metasedimentary gneisses, that are in many places gneissic tectonites. Interlayered with these supracrustal rocks are several large bands of mafic to intermediate orthogneiss of tonalitic to dioritic composition. The quartzo-feldspathic metasedimentary gneisses are deformed, in places mylonitic, feldspathic meta-arenite locally containing interlayers of metaquartzarenite. Also within this unit occur granitoid gneisses of uncertain origin.

The Eastern Subdomain contains a notable proportion of small, massive to gneissic intermediate to mafic intrusive rocks (described below). The contacts of these younger intrusive rocks with the older retrograded and layered gneisses are tectonically reworked.

Massive to gneissic anorthosite suite rocks (described below) form numerous boudinaged narrow sills and tectonic inclusion trains in the older, layered gneisses of the subdomain.

YOUNGER MAFIC TO INTERMEDIATE PLUTONIC ROCKS

A younger series of metamorphosed mafic to intermediate plutonic rocks, most of which are sills and dikes, were emplaced at successive stages into the rocks of the Parry Sound Domain. Most intrusive contacts have been tectonically modified, and crosscutting relationships have been transposed during several periods of deformation. During the last major deformation which accompanied northwesterly directed overthrusting of the Parry Sound Domain onto the Britt Domain (the Grenville Orogeny), these intrusions were boudinaged by anastomosing shears, and most are tectonically disrupted at varying scales. Isolated tectonic inclusions, in places, tectonic inclusion trains of these metaplutonic rocks, have been tectonically incorporated into the country rock high strain tectonites. In order of interpreted decreasing age these plutonic rocks are:

1. intermediate to mafic intrusive rocks
2. anorthosite suite intrusive rocks
3. mafic dikes

The intermediate to mafic intrusive rocks occur mainly within the Eastern Subdomain of Parry Sound Domain. They consist of relatively massive, lineated, and gneissic quartz diorite, diorite, tonalite, and locally, granodiorite that exhibit granulite and retrograde amphibolite facies overprint on granulite facies.

The anorthosite suite rocks, in contrast to the older diorite group, were subjected only to the latter amphibolite metamorphism that accompanied the Grenville Orogeny. They form sill-like bodies in both subdomains of Parry Sound Domain as well as variably sized tectonic inclusions in the PSDBZ and the Whitestone Lake Structural Complex. The larger bodies, namely the Whitestone Anorthosite and the sill-like bodies near the village of Dunchurch, exhibit well preserved primary compositional layering. The following massive to gneissic anorthosite suite rocks were observed: oikocrystic gabbroic anorthosite, oikocrystic anorthosite, anorthosite, anorthositic gabbro, and pyroxenite. Anorthosite is the dominant phase in the central part of the Whitestone body. The smaller boudinaged lenses and tectonic inclusions in the Eastern Subdomain and the PSDBZ are mainly gabbro anorthositic gneisses.

Late tectonic mafic dikes of predominantly amphibolitic composition concordantly intrude, and in places crosscut, rocks of the anorthosite suite and the intermediate to mafic rocks. These amphibolite dikes are commonly boudinaged and in many places strongly disrupted. They are too small to be shown on Figure 028.1.

ECONOMIC GEOLOGY AND RECOMMENDATIONS FOR FUTURE EXPLORATION

The map area contains no documented mineral deposits.

Certain lithologies in the map area should, however, be considered as potential exploration targets for the following types of metallic and nonmetallic mineral deposits:

1. Igneous layered anorthosites like the Whitestone Anorthosite and the smaller sill-like bodies of gabbroic anorthosite to the west and east of the village of Dunchurch may represent potential sources of titanium, vanadium, and platinum group metals. In the Whitestone Anorthosite body, no sulphide mineralization was observed. However, magnetite and ilmenite occur as disseminations in amounts of 1 to 3 percent (Lacy 1960; Mason 1969) throughout its broad, compositionally layered, predominantly gabbroic meta-anorthosite marginal phase. Within this marginal phase, thin interlayers of metagabbro and metapyroxenite were locally observed by the author, particularly along its northern contact. In the eastern part of the map area, sills and lenses of anorthosite suite rocks tend to be more mafic in composition than those in the Whitestone Anorthosite. Minor disseminated pyrite was locally observed in a metagabbro to metapyroxenite interlayer within the gabbroic anorthosite sill that is exposed along the southeastern shore of Whitestone Lake southeast of the Village of Dunchurch.

   Anorthosite is also a potential source of aluminum and of high-alumina ceramic material.
2. Granite pegmatite dikes are common throughout the map area, particularly in the PSDBZ and the Whitestone Lake Structural Complex. They are a potential source of high purity silica, potash feldspar, radioactive minerals, and rare earth elements. Allanite, a source of rare earths elements, in particular cerium, forms locally abundant porphyroblasts in some of the blasto-mylonitized granite pegmatite dikes that are interlayered with the tectonites within the bounding tectonic zones in Parry Sound Domain.
3. Marble is a potential source of high purity calcite, basic refractories, and flux in the filler industry. Most of the marble units within the map area are strongly deformed and contain tectonic inclusions. Some marble occurrences, in the tectonic breccias to the south of the map area, along the strike extension of the disrupted marble units in

the present area, however, have been tested as potential sources of high purity calcite (Assessment File Research Office, Ontario Geological Survey, Toronto).

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029. Anson Area, Haliburton and Victoria Counties, and Muskoka District

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INTRODUCTION

The Anson area is located 140 km northeast of Toronto and includes parts of Anson, Digby, Hindon, Longford, Lutterworth, Minden, and Oakley Townships. The map area covers about 270 km^2 and is bounded by Longitudes 78°45'W and 79°00'W and by Latitudes 44°52'30"N and 45°00'00"N. The Town of Minden lies 1 km east of the east central boundary of the map area, and access is provided by a township road, several bush roads and snowmobile trails, and float-equipped aircraft. Till cover in the area increases to the north and west and obscures bedrock geology.

MINERAL EXPLORATION

Adams and Barlow (1910) describe serpentinized marbles in the vicinity of Bob Lake (lot 12, concession II; lot 13, concession III, Anson Township; lot 13, concession XIV, Lutterworth Township) and suggest that these rocks had potential as building stone. No other recorded mineral exploration has been conducted in the map area (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)), although Dupel Mines in 1954 and 1956 and Imperial Oil Limited, in 1972 and 1973, examined copper showings hosted by dioritic gneisses on lots 4 to 7, concession II, and lot 3, concession III and IV, Hindon Township, 3 km north of the north central boundary of the map area.

GENERAL GEOLOGY

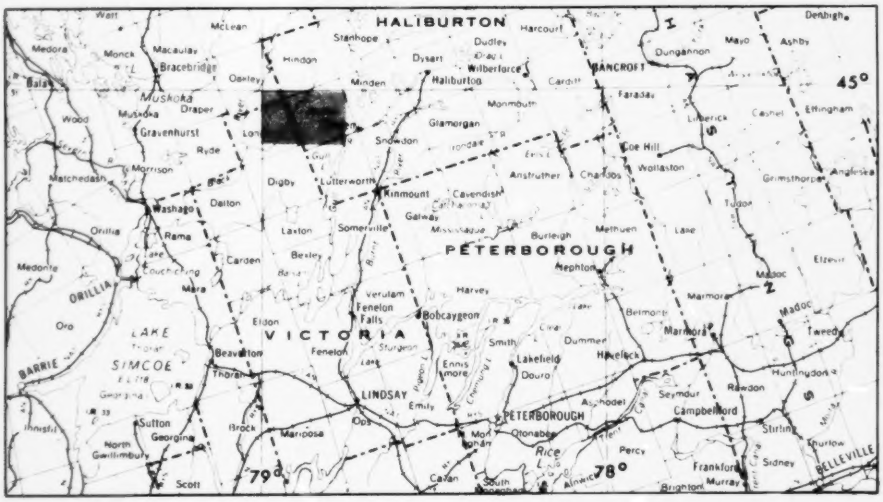
Most of the Anson area is underlain by Precambrian rocks of Middle Proterozoic age which form part of the Central Gneiss Belt of the Grenville Province. Deformed Middle to Late Proterozoic rocks of the Central Metasedimentary Belt Boundary Zone (CMBBZ) are found along the eastern boundary of the map area separating supracrustal rocks of the Central Metasedimentary Belt to the east (Easton 1985) from granitoid gneisses of the Central Gneiss Belt to the west (Figure 029.1).

Most of the lithologies present in the adjacent Digby-Lutterworth area to the south (Easton and Van Kranendonk 1984; Easton 1986) continue along strike into the Anson area (Figure 029.2). Figure 029.1 is a lithological map of the Anson map area; Figure 029.2 shows the geology of the Anson, Digby, and Highway 118 region and the main lithological groupings present in the Anson-Digby areas. Four main lithological groupings can be recognized (Figure 029.2) in the Anson area, from east to west these are:

1. deformed gneisses of the CMBBZ (Figure 029.2)
2. an area of migmatitic, dioritic, and tonalitic gneisses intruded by sills of granite gneiss (Figure 029.2)
3. an area of thinly layered, compositionally varied, migmatitic gneisses, locally containing pods and layers of anorthosite, anorthositic gabbro, and gabbro, and which contain a number of broad folds (Figure 029.2)
4. a large area of predominantly monzonite gneiss that underlies most of Longford Township (Figure 029.2).

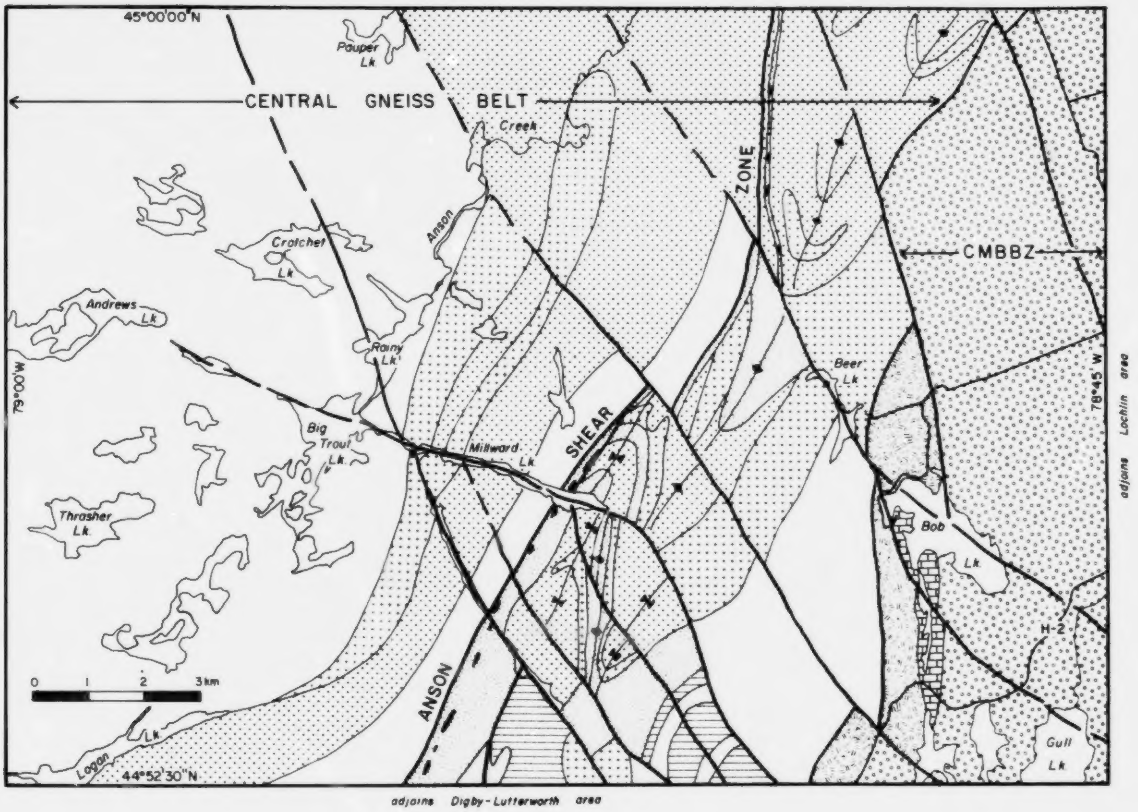
CENTRAL METASEDIMENTARY BELT BOUNDARY ZONE (CMBBZ)

Tectonically modified rocks within this zone, termed tectonites by Easton (1986) and Hanmer and Ciesielski (1984), are poorly exposed in the Anson area. Using the terminology of Hanmer and Ciesielski



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles


45°00'00"N
Pauper Lk
CENTRAL GNEISS BELT
Creek
ZONE
CMBBZ
Anson
Crotchet Lk
Andrews Lk
Rainy Lk
79°00'W
Big Trout Lk.
Millward Lk.
SHEAR
Beer Lk
78°45' W
adjoins Lochlin area
Bob Lk.
Thrasher Lk.
H-2
0 1 2 3 km
ANSON
Lk.
Logan
44°52'30"N
Gull Lk
adjoins Digby-Lutterworth area

LEGEND

CENTRAL METASEDIMENTARY BELT BOUNDARY ZONE (CMBBZ)

▨ mafic gneisses, may be derived from adjacent rocks in the Central Gneiss Belt

▨ irregularly layered gneiss, porphyroclastic gneiss

▤ dolomite marble

CENTRAL GNEISS BELT

☐ monzonite, monzogranite, granodiorite gneiss

▨ monzogranite and syenogranite gneiss

☐ granodiorite gneiss

▨ granitic gneiss with screens or partly assimilated zones of older mafic gneisses, agmatite, migmatite, breccia

▨ diorite, monzodiorite gneiss, may be comagmatic with anorthosite

▬ anorthosite, anorthoritic gabbro, gabbroic anorthosite

☐ partly assimilated tonalite gneiss derived from diorite by injection of granite sills into tonalite gneiss

▤ diorite to tonalite gneiss, locally migmatitic, minor granite sills

✚ antiform, synform, defined by gneissosity

— fault

Figure 029.1. *General geology of the Anson map area.*

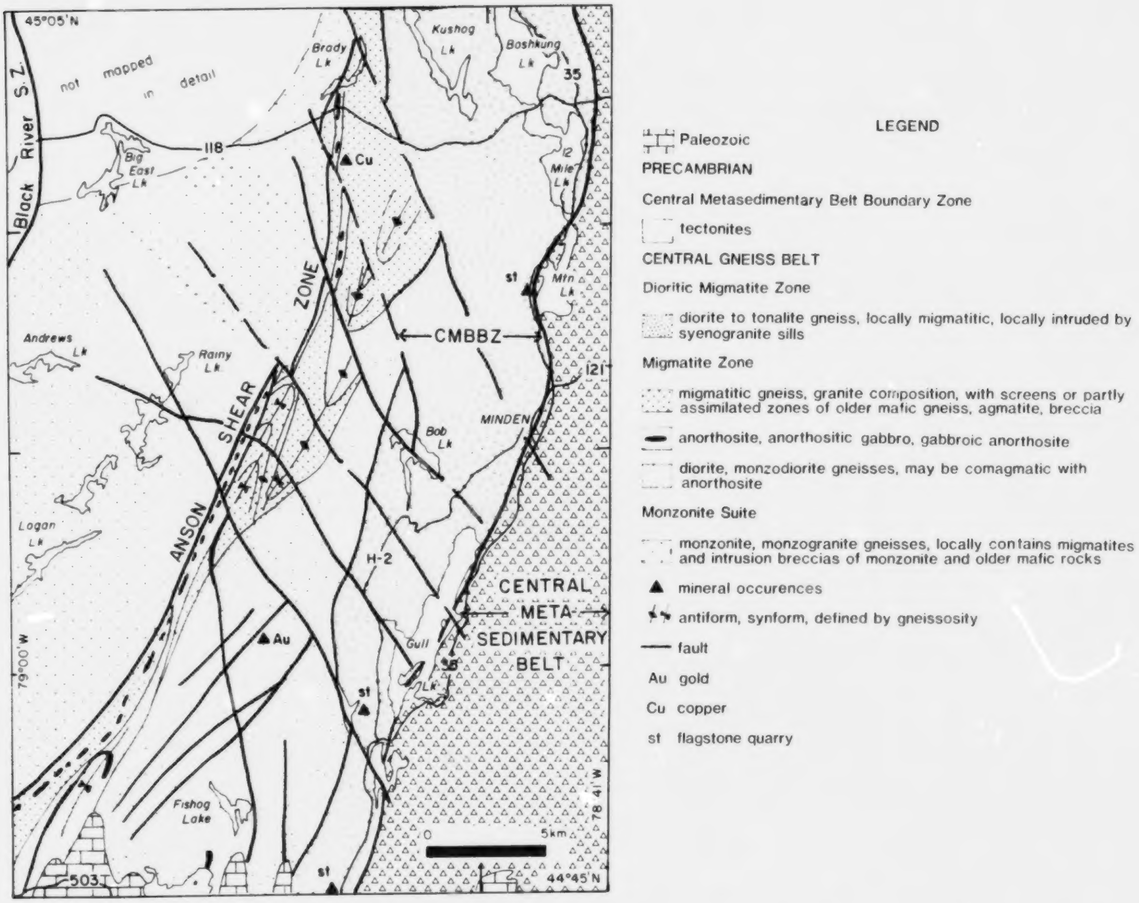

45°05'N
Black River S.Z.
not mapped in detail
118
Big East Lk
Brady Lk
Kushog Lk
Boshkung Lk
35
12 Mile Lk
Cu
st
Mtn Lk
CMBBZ
ANSON SHEAR ZONE
Andrews Lk
Rainy Lk
121
MINDEN
Bob Lk
Logan Lk
H-2
CENTRAL META-SEDIMENTARY BELT
Gull Lk
35
Au
st
79°00'W
78°41'W
Fishog Lake
0
5km
503
st
44°45'N
LEGEND
Paleozoic
PRECAMBRIAN
Central Metasedimentary Belt Boundary Zone
tectonites
CENTRAL GNEISS BELT
Dioritic Migmatite Zone
diorite to tonalite gneiss, locally migmatitic, locally intruded by syenogranite sills
Migmatite Zone
migmatitic gneiss, granite composition, with screens or partly assimilated zones of older mafic gneiss, agmatite, breccia
anorthosite, anorthositic gabbro, gabbroic anorthosite
diorite, monzodiorite gneisses, may be comagmatic with anorthosite
Monzonite Suite
monzonite, monzogranite gneisses, locally contains migmatites and intrusion breccias of monzonite and older mafic rocks
mineral occurences
antiform, synform, defined by gneissosity
fault
Au gold
Cu copper
st flagstone quarry

Figure 029.2. *Major tectonic and geologic features, lithologic packages, and mineral occurrences in the Digby-Lutterworth, Anson, and Highway 118 areas.*

(1984), the main tectonites exposed in the map area are irregularly layered and porphyroclastic gneisses. Adjacent to the contact with the Central Gneiss Belt, rocks in the CMBBZ are more highly deformed equivalents of units in the Central Gneiss Belt, an observation previously made in the Digby-Lutterworth area (Easton and Van Kranendonk 1984). A sliver of clean dolomite marble lies within the CMBBZ on the southwestern shore of Bob Lake (Figure 029.1), and is the unit Adams and Barlow (1910) considered to be potential building stone. The trace of the CMBBZ/Central Gneiss Belt contact is considerably offset by northwest-trending faults in the area (Figures 029.1 and 029.2).

DIORITIC MIGMATITIC GNEISS ZONE

This group of rocks consists of migmatitic, protomylonitic diorite, granodiorite, and tonalite gneisses with a quartz-plagioclase leucosome lying between the Anson Shear Zone and the CMBBZ (Figure 029.2). These rocks are intruded to varying degrees by syenogranite sills, which locally assimilated and mixed with the mafic rocks. These rocks correspond in part to the "older diorite group" of Easton and Van Kranendonk (1984). This zone appears to be structurally overlain by rocks of the CMBBZ in the northeastern part of the map area (Figure 029.2).

MIGMATITE ZONE

A 1 to 5 km wide zone of thinly layered, compositionally varied, migmatitic gneisses transects the map area from southwest to north-northeast (Figure 029.2). Gneisses within this zone are locally agmatitic, nebulitic, stromatic, intrusion breccias, or injection migmatites. Some are protomylonitic and locally porphyroclastic, and show some characteristics of the irregularly layered gneisses of the CMBBZ. Within this zone of migmatites is a boudinaged anorthosite sheet which can be traced for a distance of more than 20 km from the southwestern corner of the Digby area to the northern shore of Millward Lake (Figure 029.2). The sheet reappears northwest of Beer Lake and can be traced north to Highway 118, 5 km north of the map area. In addition to anorthosite, gneissic anorthosite, and gabbroic anorthosite, a group of diorite, quartz monzodiorite, and monzodiorite rocks is associated with this boudinaged anorthosite sheet and together with the anorthositic rocks form a useful marker horizon.

Also within this zone are a number of 1 to 2 km wavelength antiforms and synforms which can be traced along the length of the zone (Figures 029.1 and 029.2), which are defined both by lithological repetition and dip reversals. This is the only part of the map area where such large scale folding is so continuous and well defined.

In the Anson area, the western contact of this zone coincides with the Logan Lake Shear Zone of Schwerdtner and Mawer (1982). Based on mapping in the Anson area and along Highway 118 near Anson Creek, the author concurs that the western margin of this zone does represent a shear zone. This shear zone separates mainly dioritic gneisses and syenogranite sills to the east from monzonitic rocks to the west (Figure 029.2), and that this shear zone probably represents a thrust (Schwerdtner and Mawer 1982). The shear zone does not veer west through Logan Lake as shown by Schwerdtner and Mawer (1982), but rather continues to the southwest through the Digby-Lutterworth area as shown in Figure 029.2. A number of mylonite zones in the Digby-Lutterworth area (Easton 1986) may be splays related to this structure. Because the shear zone does not pass through Logan Lake, it is proposed that the shear zone be renamed the Anson Shear Zone, as it lies along Anson Creek in Anson Township.

MONZONITE SUITE ROCKS

The western half of the map area is underlain by a suite of monzonitic to monzogranitic rocks (Figure 029.2). These rocks are compositionally varied, and have xenolith-rich zones up to several hundred metres in width. The proportion of xenoliths increases to the north and northwest, and these rocks take on a more migmatitic and agmatitic character. Similar rocks in the Digby-Lutterworth area are regarded to be plutons by Easton and Van Kranendonk (1984); if so, then the monzonite suite rocks seen in the Anson area may be the marginal phases of plutons. It is equally probable that the monzonite suite rocks were intruded as a series of closely spaced sheets, rather than as large mesozonal plutons.

METAMORPHISM AND STRUCTURAL GEOLOGY

Metamorphic grade in the Anson area is upper amphibolite facies, although granulite facies rocks are present on Highway 118, 4 km north of Pauper Lake (Figure 029.1). Patches of yellow-coloured, weathered monzonite are common in the northwestern part of the Anson area, and may represent the incipient development of granulite facies metamorphism.

Deformation in rocks of the Central Gneiss Belt is greatest near the CMBBZ, and decreases westward. A prominent southeast-plunging lineation is present in all lithologies in the CMBBZ, and is also well developed in rocks of the Central Gneiss Belt as far west as the Anson Shear Zone.

A series of north-northwest trending faults cuts across the Anson area, and displace all units, including rocks within the CMBBZ (Figure 2). Late faults in the Digby-Lutterworth area trend northeast, and the two sets may be conjugate (Figure 029.2). These faults offset all major Precambrian structures and units, including the CMBBZ (Figure 029.2).

ECONOMIC GEOLOGY

Longford Township is underlain almost entirely by monzonite and monzogranite gneisses similar to units in the Digby-Lutterworth area, none of which contain any unusual trace element or metal contents (Easton 1986, and unpublished data). Apart from use as building stone, these rocks show limited economic potential at present.

Within the migmatite zone, gabbroic and dioritic gneisses containing disseminated chalcopyrite and bornite are present on lots 4 to 7, concession II, and lots 3, concessions III and IV, Hindon Township, 3 km north of the map area. Dupel Mines Limited and Imperial Oil Limited reported average grades of 1 to 2 percent copper (Assessment Files Research Office, Ontario Geological Survey, Toronto). Similar gneisses are present in the Anson area in the migmatite zone east of the Anson Shear Zone.

Gold has been reported in the dioritic migmatitic gneisses in the Digby-Lutterworth area (Easton 1986). The overall mafic composition of the gneisses suggests that they may be favourable host rocks for base metals such as copper, as well as gold.

Within the CMBBZ, relatively pure dolomite marble near Bob Lake could be used for building or crushed stone, or as a source of magnesium carbonate for a variety of industrial purposes. Flagstone potential is limited within the Anson area. More favourable prospects occur in the adjacent Lochlin area to the east (Easton 1985).

Sand and gravel is present in the eastern part of the map area, associated with the Gull River system. A number of quarries are operating in, and adjacent to, the map area and supply the Minden area. Extensive till cover over much of the Anson area may allow the use of till sampling as an exploration tool.

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030. Paleoenvironment and Facies of the Apsley Formation, Peterborough County

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INTRODUCTION

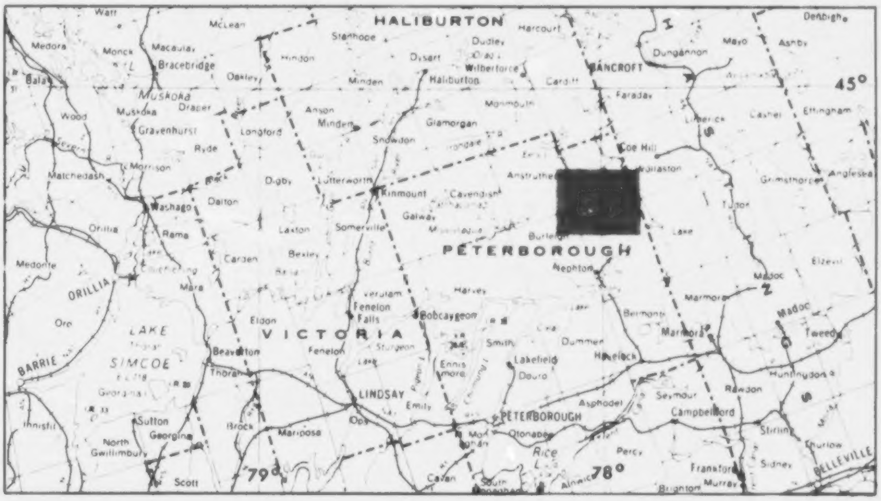
The Apsley Formation (Shaw 1962) or Apsley Gneiss (Shaw 1962, 1972) crops out over 140 km^2 in parts of Anstruther, Burleigh, Chandos, and Methuen Townships in Peterborough County near the Village of Apsley, located on Highway 28, 55 km north of Peterborough. The protolith of the formation has long been problematic. Simony (1960), Shaw (1962), Lumbers (1967), and Bright (1977, in press) considered the Apsley Formation to be sedimentary in origin, whereas Shaw (1972) and van de Kamp (1968) suggested a volcanic or mixed volcanic-sedimentary protolith on the basis of geochemistry. If the Apsley Formation is volcanic in origin, then it might have greater mineral potential than previously expected. Four weeks during the 1986 field season were spent conducting detailed mapping, stratigraphic, and facies studies of the Apsley Formation (Mayo Group) in order to better determine its origin and mineral potential. This report presents the results of this specialized study on the Apsley Formation.

MINERAL EXPLORATION

Although metavolcanics and metasediments of the Hermon Group in the Apsley region have been extensively explored for uranium and base metals (Bright 1980, in press; OGS 1984), little mineral exploration has been conducted in the predominantly carbonate and siliceous clastic metasediments of the Mayo Group which include the Apsley Formation. Previous exploration work is summarized in the Geological Data Inventory Folio for Chandos Township (OGS 1986). An iron and a copper showing are both present in the East Road gneiss east of Lasswade (Figure 030.1). The East Road gneiss has been considered (e.g. Lumbers 1967) to be correlative with the Apsley Formation. The East Road gneiss occurrences are adjacent to a granite pluton which may be responsible for the mineralization. Gold has been reported from concession II of Chandos Township, but no lot number or host lithology was specified (Ontario Bureau of Mines 1900). Many parts of the Apsley Formation are rusty-weathering, with pyrite and pyrrhotite the most common sulphide minerals (Shaw 1962), but to the best of the author's knowledge, none of these gossan zones has been examined systematically.

GENERAL GEOLOGY

The Apsley area lies within the Central Metasedimentary Belt of the Grenville Province and is underlain by Middle Proterozoic supracrustal rocks of the Grenville Supergroup which are in turn cut by a variety of Middle to Late Proterozoic intrusive rocks. The Grenville Supergroup has been divided into two groups (Hewitt and James 1956; Lumbers 1967): the Hermon Group, a dominantly metavolcanic and clastic metasedimentary sequence, overlain by the Mayo Group, a carbonate succession. Metamorphic grade in the area ranges from lower amphibolite in the Lasswade area and increases toward the northwest to middle to upper amphibolite facies. The Apsley area lies within the Elzevir Terrane (Brock and Moore 1983) of the Central Metasedimentary Belt, near the boundary with the Bancroft Terrane; the boundary approximates the trace of the Eel's Creek and Pratt's Creek Faults (Figure 030.1). Detailed mapping of Anstruther, Chandos, and Methuen Townships was conducted by Bright (1981), Shaw (1962), and Hewitt (1961), respectively. The Eel's Creek area (NTS 31 D/16) and the Burleigh Falls area (NTS 31 D/9) were mapped by Bright (1980, in press). Supracrustal rocks



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

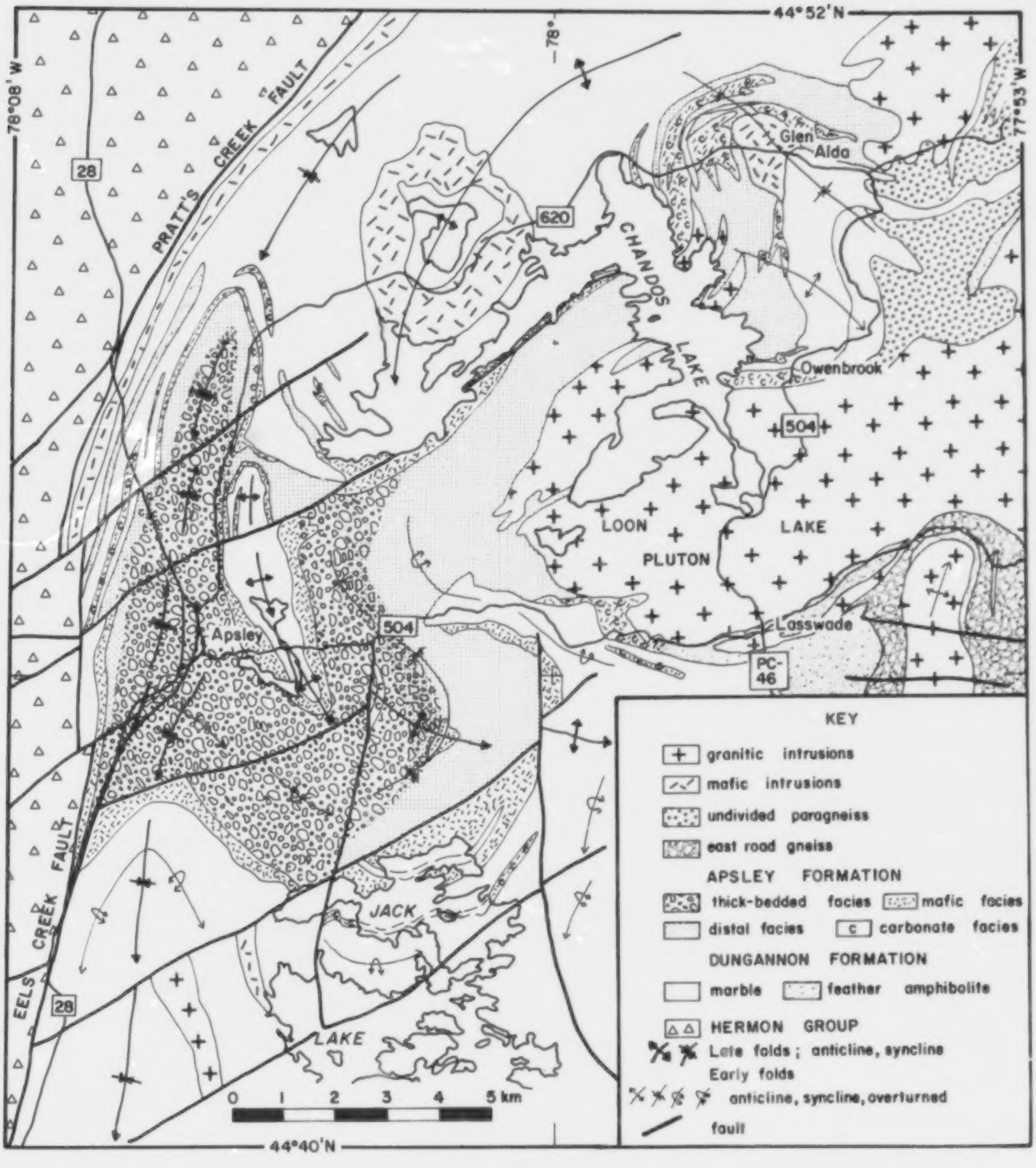

44°52'N
78°
78°08'W
77°53'W
28
PRATT'S CREEK FAULT
620
CHANDOS LAKE
Glen Alda
Owenbrook
504
LOON LAKE PLUTON
Apsley
504
Lasswade
PC-46
EELS CREEK FAULT
28
JACK LAKE
0 1 2 3 4 5 km
44°40'N
KEY
granitic intrusions
mafic intrusions
undivided paragneiss
east road gneiss
APSLEY FORMATION
thick-bedded facies
mafic facies
distal facies
C carbonate facies
DUNGANNON FORMATION
marble
feather amphibolite
HERMON GROUP
Late folds ; anticline, syncline
Early folds
anticline, syncline, overturned
fault

Figure 030.1. Geological map showing the distribution of the Apsley Formation and its various facies.

of the Mayo Group in the map area have been divided into three formations (Shaw 1962, 1972; Lumbers 1967); the marbles of the Dungannon and Lasswade Formations and quartzofeldspathic gneisses of the Apsley Formation.

APSLEY FORMATION

Definition and Description

As defined by Shaw (1962), the Apsley Formation consists of a lower member which includes hornblende-biotite quartzofeldspathic gneiss (para-amphibolite), and feather amphibolite, and an upper member of biotite quartzofeldspathic gneiss. This usage is retained in this report, with minor modification based on mapping of variation within the Apsley

Formation. Shaw (1962) did not pinpoint a type locality, but did specify that the type locality was near the village of Apsley. The reference sections listed here for the facies types of the Apsley Formation can also be considered as reference sections of the Apsley Formation.

Lumbers (1967) correlated the Apsley Formation with several other bands of siliceous clastic metasediments in Cardiff, Faraday, Methuen, and Wollaston Townships. None of these bands are continuous with the Apsley Formation in the Apsley area, nor are they lithologically similar or likely equivalents of the Apsley Formation, although they may have been deposited at roughly the same time as the Apsley Formation.

Four facies of mappable extent have been recognized within the Apsley Formation:

1. a thick-bedded facies
2. a thin-bedded or distal facies
3. a mafic facies
4. a carbonate facies

In general, the thick-bedded and distal facies correspond to the upper, and volumetrically larger, member of the Apsley Formation, with the mafic and carbonate facies constituting the lower member. The demarcation between the lower and upper members of the Apsley Formation is best developed in the southern part of the area, where the mafic facies (lower member) is overlain by the thick-bedded facies (upper member). Distinction of the lower and upper members is more poorly developed in the north where the boundaries between the distal facies (upper member) and the mafic and carbonate facies (lower member) are complexly interfingered. Figure 030.1 shows the distribution of the four facies types within the Apsley Formation, and is based on a number of measured sections as well as detailed mapping. Sparse outcrop and extensive lichen cover in parts of the area prevents facies assignment for all of the Apsley Formation. The characteristics of each facies are described briefly below. The granulometric classification for volcanic rocks follows that given by Easton and Johns (1986). Volcanic terminology is used in this report, but these rocks could be equally as well described as sedimentary rocks. For descriptive purposes, the various facies are described as unmetamorphosed rocks.

Facies

Thick-bedded Facies Reference sections for this facies are located on Highway 28, 500 m north of the Highway 28/620 junction in the Village of Apsley (UTM co-ordinates E 073000, N 496100 and E 073010, N 496088, Zone 17). This facies consists dominantly of coarse ash, generally with planar bedding on the scale of 5 to 10 cm, 30 to 60 cm, 1 to 3 m and 8 to 14 m. Massive beds from 3 to 14 m thick are commonly interbedded with 5 to 10 and 30 to 60 cm thick beds; the thinner units commonly show internal planar or wavy laminations. Cross lamination is not common, although convolute lamination and other soft-sediment deformation features are preserved. Beds of monolithic lapilli-ash tuff, ash tuff-breccia and tuff-breccia, 30 to 100 cm thick, are locally present in this facies, and may be matrixor clast-supported (Photo 030.1). Many of these coarse pyroclastic deposits are channelized. In addition to these distinctive breccias, a number of beds are present containing "ovoid nodules" (Simony 1960). Some are "floating" in ash beds, and may represent concretions (Simony 1960) or gas escape structures. Others occur in discrete horizons, and exhibit grading, and may represent flattened pumice. Graded beds, showing reverse and normal grading, are present in outcrop; reverse grading is recognized most easily where load casts and scouring provide addi-

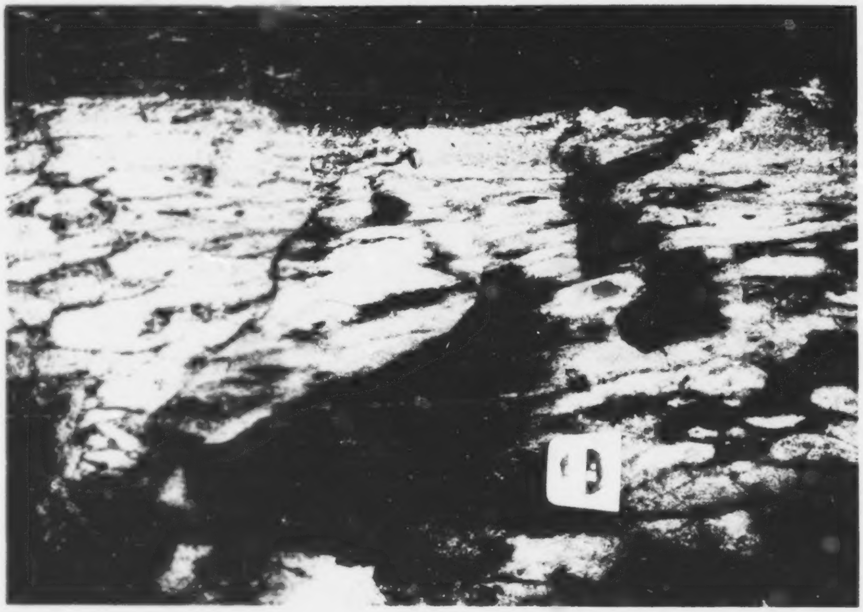


Photo 030.1. *Tuff-breccia horizon in thick-bedded facies of the Apsley Formation, Highway 28, 500 m north of the Highway 28/620 junction in Apsley.*

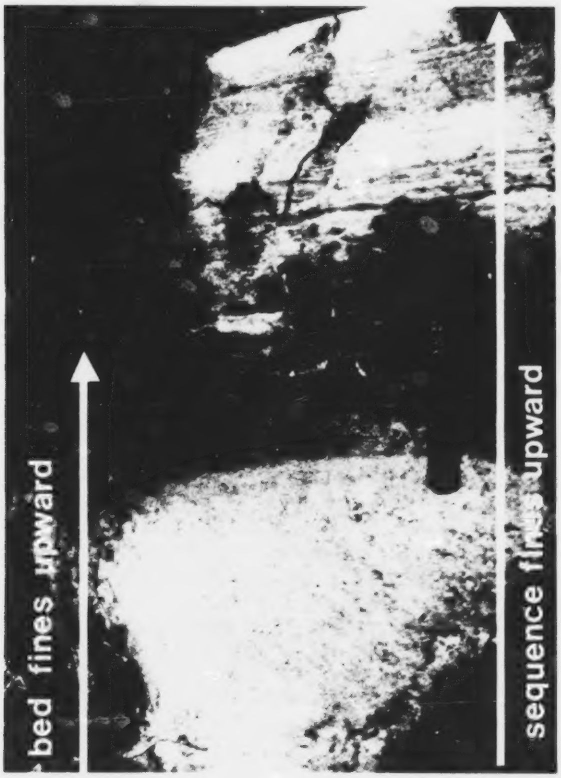


Photo 030.2. *Doubly graded sequence in thick-bedded facies of the Apsley Formation, Highway 28, 500 m north of the Highway 28/620 junction in Apsley. The lower bed is graded, consisting of a lapilli-tuff base and a coarse ash top. The sequence is graded, with fining of ash beds toward the top of the photo.*

tional top indicators. All bedding thickness ranges show evidence for scouring during deposition, and channels on the scale of 1 to 2 m to 50 to 60 m across are visible in outcrop. Many channels are only recognized when comparing closely-measured sections. In the 10 cm and 30 to 60 cm thick beds, dewatering structures, mainly dish and pillar structures (Lowe 1975) and convolute laminations, are present. Doubly-graded beds (Photo 030.3) are present, and are indicative of deposition of material by subaqueous pyroclastic flows (Fiske 1963; Easton and Johns 1986). Fining- and coarsening-upward sequences on the scale of 20 to 50 cm are also apparent in measured sections. All features observed in this facies are typical of those observed in "massive sandstones" in turbidite fans (Walker 1978, 1984) and represent rapid deposition of material. Primary textures are best preserved in this facies of the Apsley Formation, probably because of the uniform grain size and composition, and thick-bedded character of the sequence.

Thin-bedded (Distal) Facies A reference section for this facies is located on an island in Chandos Lake (UTM co-ordinates E 026635, N 496540, Zone 18). This facies differs from the thick-bedded facies in that maximum bed thickness is generally >1 m, compositional layering is better defined, beds are less massive, commonly with planar to wavy-laminated tops and massive bases, and grading is more obvious (Photo 030.3). Calc-silicate and calcareous ash interbeds are present locally; no lapilli or breccia material is present and overall grain size is fine to coarse ash. Plagioclase porphyroblasts are common, and cut all layering and primary textures in the rocks, particularly in the finer ash beds. On the northern shore of Chandos Lake, rocks of this facies are interbedded with marbles of the Dungannon Formation. Unlike the carbonate facies rocks, marble and ash beds retain their distinct compositional character.

Carbonate Facies Reference sections for this facies are located on Highway 28 1.7 km north of the Highway 28/620 junction (UTM co-ordinates E 072955, N 496210 and E 072930, N 496275, Zone 17). Rocks of this unit have been included by all previous workers as part of the Apsley Formation. This facies consists of calcareous ash, fine to coarse ash, planar bedded on the scale of 2 to 50 cm, and locally, rare thick beds of coarse ash. The ash units are interbedded with calc-silicate, feather amphibolite, and impure and pure calcitic and locally dolomitic marbles; the interbedding occurs on the scale of 2 to 20 cm and 1 to 3 m. Grey, fine-grained hornblende-biotite-garnet ash beds are also common. Plagioclase and garnet porphyroblasts are present in many ash beds in this facies. Rhythmically layered sequences consisting of 2 to 5 cm thick ash layers capped by 1 to 2 cm of calc-silicate or fine-grained calcite marble (Photo 030.4) are characteristic of this facies. These couplets are interpreted to represent turbidites, with the calc-silicate/marble top representing carbonate and ash settling out of suspension. Unlike the distal facies, ash and carbonate are intermixed both lithologically and mineralogically.

Mafic Facies Reference sections are located on Highway 504, 1.4 km east of Apsley (UTM co-ordinates E 073160, N 0495955, Zone 17) and Highway 28, 5 km south of Apsley (UTM co-ordinates E 072835, N 0495580, Zone 17). These rocks are similar to those present in the thin-bedded facies, except that they consist of hornblende-biotite ash and are darker in colour. Some units show weakly developed feather amphibolite texture. No thick beds of lapilli tuff or tuff-breccia are present in this facies, and the facies, at its base, interfingers over a stratigraphic interval of 1 to 2 m with the Dungannon Formation. This facies is less than 20 m thick, and appears only at the base of the Apsley Formation.

Transitional facies exist locally which show attributes of either the thick-bedded and thin-bedded or the thin-bedded and carbonate facies, as might be expected. The thickness of the Apsley Formation is difficult to estimate; Bright (1977, in press) estimated 300 m or less. Measured sections through the thick-bedded facies on Highway 28 indicate a minimum thickness of this facies of 200 m, an overall thick-

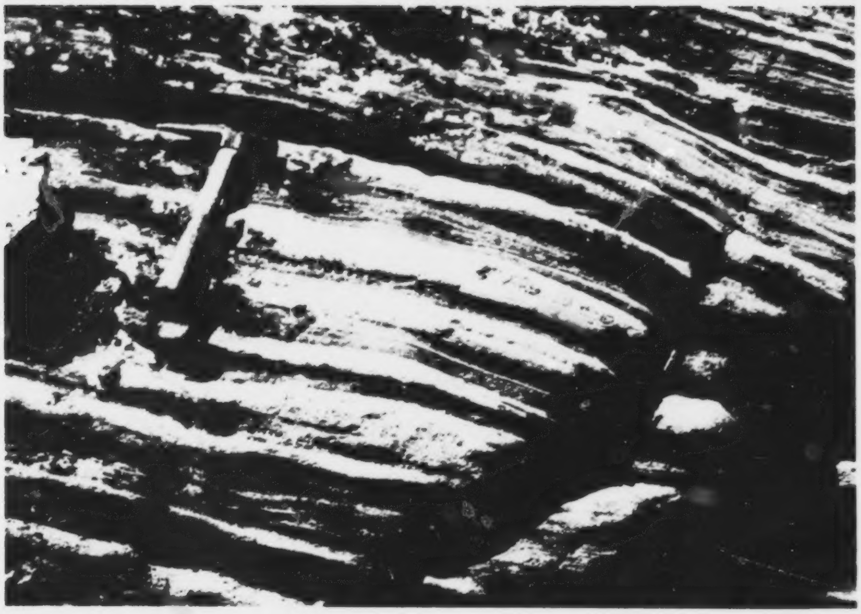


Photo 030.3. *Turbidites of the thin-bedded (distal) facies of the Apsley Formation. Coarse ash bases form the resistant layers. Photo taken at Chandos Lake.*

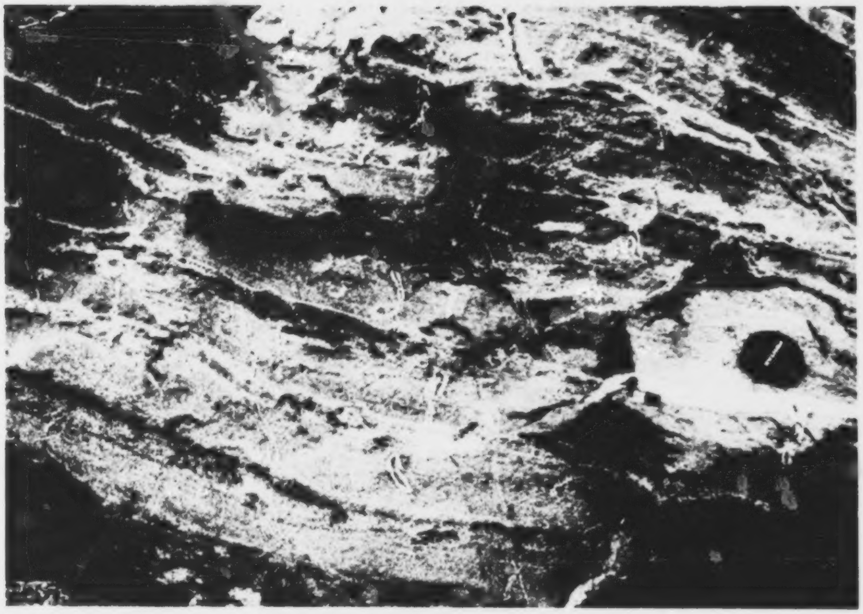


Photo 030.4. *Calcareous ash beds with calc-silicate layers forming a rhythmic sequence in the carbonate facies of the Apsley Formation. Ash/calc-silicate pairs were probably deposited by turbidity currents. Photo taken from Highway 28, 1.5 km north of Apsley.*

ness of the whole formation is 300 to 500 m is likely. Before the relationship of these four facies types is discussed, it is necessary to briefly review the character of the Dungannon Formation which underlies and interfingers with the Apsley Formation.

DUNGANNON FORMATION

The Dungannon Formation in the Apsley area has been described by Shaw (1962) and Bright (1980, in press). The type area of the formation is in Dungannon Township (Hewitt and James 1956), over 35 km to the northeast of Apsley and consequently, time-equivalence between lithologically similar marbles in the Apsley area and the type area is uncertain.

Briefly, the Dungannon Formation in the Apsley area consists of medium- to coarse-grained, thickly laminated to thin-bedded, siliceous calcitic to locally dolomitic marble and impure marble, and thin interbeds of feather amphibolite (basic metatuff), meta-arenite, metawacke, and calcareous metawacke. Although metamorphism has obliterated some original textures in the Dungannon Formation marbles, it is still possible to make some inferences about its depositional environment. The presence of well segregated, regularly-bedded, repetitive sequences indicate a deep water depositional environment (McIlreath and James 1984; Bourque 1981). The presence of interbeds of cherty material, calcareous metasiltstone, quartz and other detritus, and the lack of *in situ* biosedimentary structures common in shallow water Grenville environments (Bourque 1981; Bartlett *et al.*, in press), as well as the occurrence of carbonate deposition during hiatuses in deposition of metatuff of the Apsley Formation also indicate a deep water setting (McIlreath and James 1984; Cook and Mullins 1983). The presence of all these features indicates probable deposition by turbidity currents since even relatively minor amounts of clastic detritus can swamp primary carbonate production in a basin (Wilson 1975). The presence of marble conglomerates and graded bedding in thinly laminated marbles in Wollaston Township (Hewitt 1962) is also consistent with deep water turbidite deposition. A number of outcrops on Highways 28 and 620 in the Dunganon Formation contain lensoid bedding truncations, cutoffs, convoluted bedding, and minor folding, which may be carbonate slides and slumps, a common feature of thin-bedded carbonate deposits in the slope-basin facies (Cook and Mullins 1983). To summarize, the Dungannon Formation in the Apsley area represents a carbonate slope-basin margin environment containing mainly detrital carbonate material deposited by turbidity currents, consistent with the inferred depositional setting of the Apsley Formation.

It is likely that a number of carbonate depositional environments are present in the Dungannon Formation. For example, near the Village of L'Amable, south of Bancroft on Highway 62, clustered columnar stromatolites are present in dolomitic marble of the Dungannon Formation and probably represent a high-energy intertidal environment (Wilson 1975). Also, in the type areas of the Dungannon Formation, dolomite marbles predominate over calcitic marbles (Hewitt and James 1956). The opposite is true in the Apsley area, and probably reflects different depositional settings. Figure 030.2 shows the relationship of possible depositional settings in the Apsley area with those present in the Haliburton-Bancroft-Apsley region. Given the number of major depositional settings present in the region, it cannot be assumed that deposition of the Dungannon Formation occurred simultaneously across the region or that the Dungannon Formation everywhere overlies the Hermon Group (*see* section on "Discussion").

LASSWADE FORMATION

Shaw (1962) introduced the term "Lasswade Formation" (also called the Lasswade Marble) for impure, thin-bedded marbles present in the areas of Highway 504 and Peterborough County Road 46 east of Apsley. These rocks are lithologically similar to the Dungannon Formation, and in the Apsley area it is unlikely that the two marbles could be distinguished on the basis of lithology. The structural evidence that the Lasswade Marble east of Apsley overlies the Apsley Formation (Shaw 1962, Lumbers 1967) is weak, and in fact, Bright (1980, in press) suggests that the Lasswade Marble underlies the Apsley Formation. The facies present in the Apsley Formation are also consistent with this interpretation. As presently defined, the Lasswade Marble is not lithologically distinct from the Dungannon Formation, and it is unclear that the Lasswade Formation overlies the Apsley Formation. Since carbonate sedimentation continued during deposition of the Apsley Formation, and the Apsley Formation is wedge-like in extent, it is most likely that the Dungannon Formation underlies, interfingers with, and overlies the Apsley Formation, and that designation of the Lasswade Marble as a stratigraphic unit serves little purpose. Hence it is recommended that use of the term Lasswade Formation be discontinued.

FACIES MODEL AND PALEOGEOGRAPHY OF THE APSLEY FORMATION

PYROCLASTIC FAN MODEL

The facies types in the Apsley Formation can be related to each other, and regional paleogeography determined by, the facies model illustrated in Figure 030.3. The proposed pyroclastic fan facies model for Apsley Formation deposition is based on two existing facies models. The first is a model for deposition of subaqueous pyroclastic flows as turbidity currents (Fiske and Matsuda 1964; Fiske 1963), which explains deposition of individual beds or sequences of beds, particularly within the thick-bedded facies of the Apsley Formation. The second is Walker's (1978, 1984) model for submarine fan deposits (turbidites) which explains deposition of the entire Apsley Formation and its contact relationships with the Dungannon Formation.

The Apsley Formation was probably derived from eruption of a subaqueous volcano or an island volcano. The volcano initially may have erupted andesitic material, resulting in deposition of the mafic facies of the Apsley Formation. As the volcano grew, it began erupting mainly dacitic and rhyodacitic material which was deposited on the outer flank of the volcano by turbidite fan systems (Figure 030.3). Within the upper fan and the fan channels coarse pyroclastic deposits and massive coarse ash beds were laid down and extensive channelization occurred. Many of these deposits show the characteristics of "massive sandstones" described by Walker (1978, 1984). Thin-bedded deposits were laid down in the suprafan and mid-fan and lower fan areas, where the pyroclastic rocks interfingered with turbidites of the Dungannon Formation which were being deposited in the area from another source region by an independent distributory system (Figures 030.2 and 030.3). The Apsley pyroclastic fan prograded to the north and northeast, and buried earlier deposited Dungannon Formation marbles and distal Apsley Formation units. The top of the Apsley Formation is not exposed, so we do not have a record of waning of sedimentation in the fan, although it is likely the carbonate deposition continued and eventually buried the fan system.

The general elements of the model for Apsley Formation deposition shown in Figure 030.3 may have wider application. "Volcanic greywackes" have been reported from many areas in the Archean (e.g. Breaks *et al.* 1978; Beakhouse 1985; Ojakangas 1972). Many of these rocks have textural features suggestive of turbidite deposition, yet are dacitic in

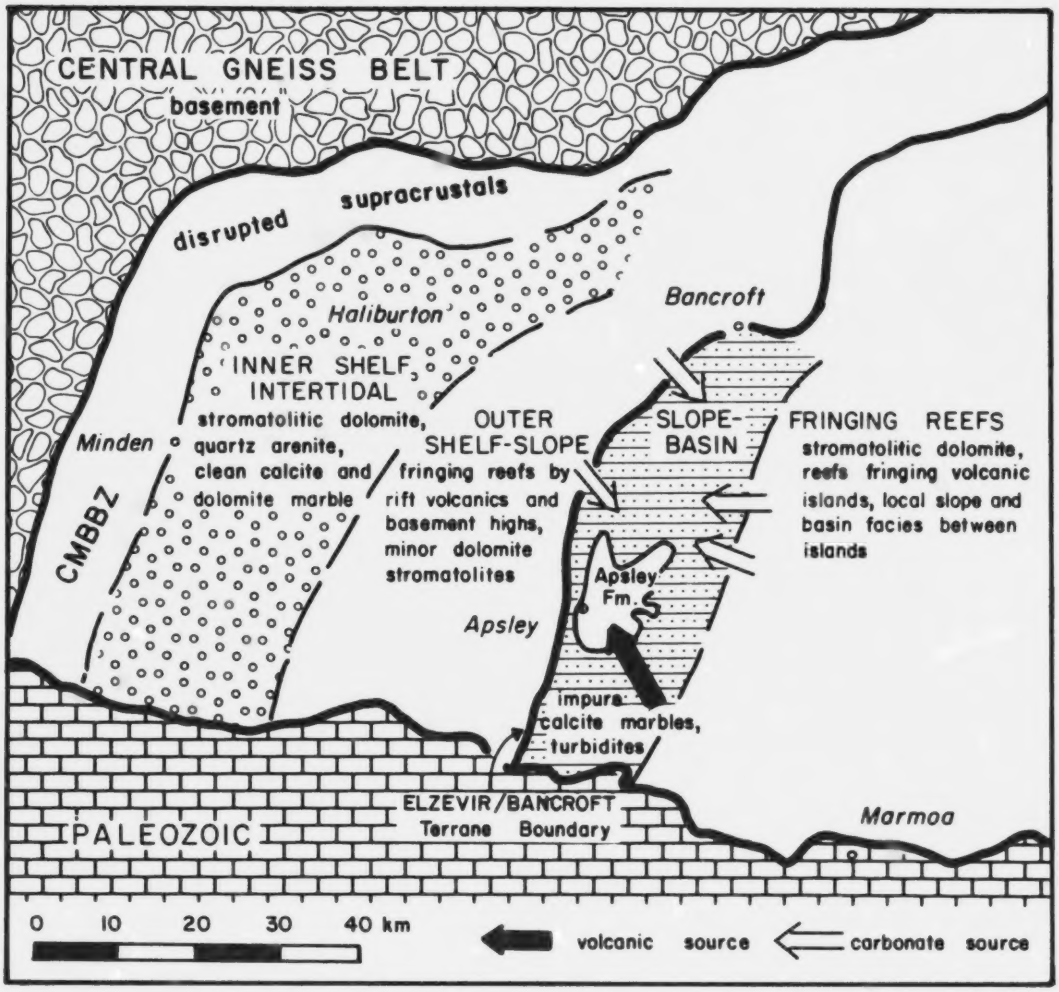

CENTRAL GNEISS BELT
basement
disrupted supracrustals
Haliburton
INNER SHELF, INTERTIDAL
stromatolitic dolomite, quartz arenite, clean calcite and dolomite marble
Minden
CMBBZ
OUTER SHELF-SLOPE
fringing reefs by rift volcanics and basement highs, minor dolomite stromatolites
Bancroft
SLOPE-BASIN
FRINGING REEFS
stromatolitic dolomite, reefs fringing volcanic islands, local slope and basin facies between islands
Apsley Fm.
Apsley
impure calcite marbles, turbidites
ELZEVIR/BANCROFT Terrane Boundary
PALEOZOIC
Marmora
0 10 20 30 40 km
volcanic source
carbonate source

Figure 030.2. *Carbonate depositional environments in the Minden-Haliburton-Bancroft-Apsley area.*

composition showing little evidence of chemical weathering (Beakhouse 1985). Many of these enigmatic rocks were probably deposited in a similar manner to the Apsley Formation.

DISCUSSION

Protolith

Shaw (1972) presented geochemical evidence that the upper member of the Apsley Formation was volcanic in origin, and van de Kamp (1968) reached the same conclusion for the lower member. The presence of lapilli-tuff, tuff-breccias, doubly graded beds and massive beds over 3 m thick in the thick-bedded facies of the Apsley Formation indicate some primary pyroclastic deposits are present in the Apsley Formation (Fiske 1963). It becomes more difficult to determine if deposits in the thin-bedded and carbonate facies of the Apsley Formation are primary deposits or resedimented. Nevertheless, the author interprets these rocks as consisting dominantly of volcanic material. Designation of these rocks as sedimentary or volcanic does not fundamentally alter the facies model presented here (Figure 030.3), as subaqueous pyroclastic flows behave as turbidity currents (Fiske and Matsuda 1964; Fiske 1963), and resedimented material in a pyroclastic fan would also be deposited by turbidity currents.

Source

The author interprets the Apsley Formation as a proximal-distal to distal facies volcanic regime. Distribution of facies indicates that the source area lay to the south, but the Apsley Formation cannot be directly traced to any known metavolcanics in the area. Dacitic and rhyodacitic metavolcanics are present 25 km south of Apsley on Stony Lake and Oak Lake (Bright, in press; Hewitt 1961) and could be proximal equivalents of the Apsley Formation.

Age

Heaman *et al.* (1984) have reported an Rb-Sr age of 1333±24 Ma from Apsley Formation samples collect-

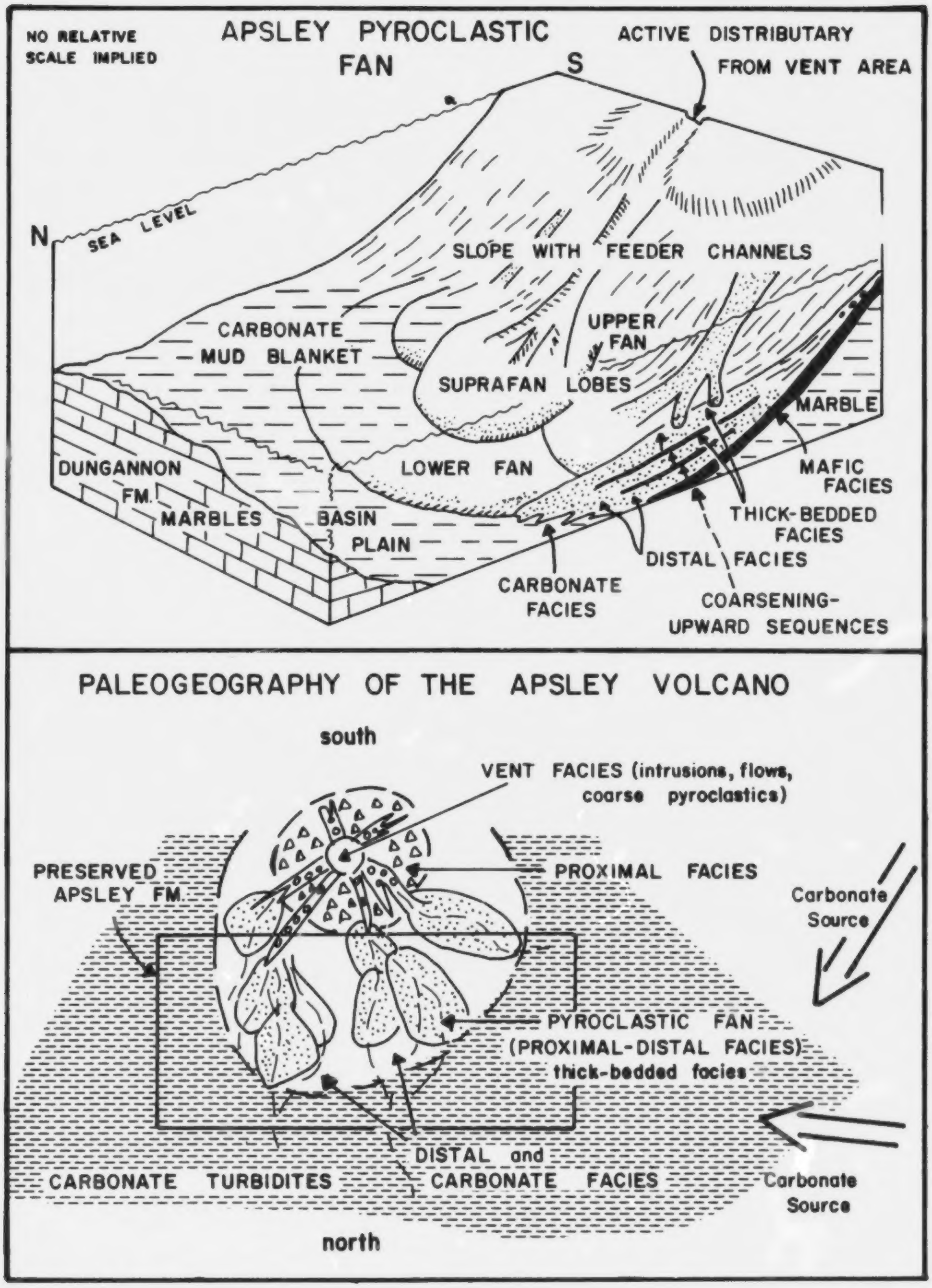

NO RELATIVE SCALE IMPLIED
APSLEY PYROCLASTIC FAN
S
ACTIVE DISTRIBUTARY FROM VENT AREA
N
SEA LEVEL
SLOPE WITH FEEDER CHANNELS
CARBONATE MUD BLANKET
UPPER FAN
SUPRAFAN LOBES
MARBLE
DUNGANNON FM.
MARBLES
BASIN PLAIN
LOWER FAN
MAFIC FACIES
THICK-BEDDED FACIES
DISTAL FACIES
CARBONATE FACIES
COARSENING-UPWARD SEQUENCES
PALEOGEOGRAPHY OF THE APSLEY VOLCANO
south
VENT FACIES (intrusions, flows, coarse pyroclastics)
PRESERVED APSLEY FM.
PROXIMAL FACIES
Carbonate Source
PYROCLASTIC FAN (PROXIMAL-DISTAL FACIES) thick-bedded facies
DISTAL and CARBONATE FACIES
CARBONATE TURBIDITES
Carbonate Source
north

Figure 030.3. *Facies Model for deposition of the Apsley Formation and inferred paleogeography. See text for details.*

ed from three outcrops of the thick-bedded facies. This age is older than U-Pb ages of 1250 Ma and 1280 Ma reported for Hermon Group metavolcanics in the region (Lumbers 1967; D. Davis, geochronologist, Royal Ontario Museum, personal communication 1986), and it is premature to state whether the Apsley Formation is equivalent in age, or older than, the Hermon Group. However, if the Apsley Formation is derived from Hermon Group volcanic centres, then it, and the associated Dungannon marbles, are lateral equivalents to the Hermon Group, and do not overlie the Hermon Group in the Apsley area. Nonetheless, it is still possible that in the type area of the Dungannon Formation, the Dungannon Formation does overlie the Hermon Group. Clearly additional studies are needed before the stratigraphic complexities of the Grenville Supergroup in the Apsley-Bancroft-Madoc area are fully understood.

ECONOMIC GEOLOGY

PRECIOUS AND BASE METALS IN GOSSAN ZONES

Gossan zones are common throughout the Apsley Formation, particularly within the thick-bedded facies, and generally contain disseminated pyrite and pyrrhotite (Shaw 1962). Three types of gossans are present in the Apsley area. Type 1 gossans are stratabound, and occur in very thickly to thinly bedded medium to coarse ash beds in the thick-bedded facies of the Apsley Formation, commonly sandwiched between very thickly to extremely thickly bedded coarse ash to lapilli ash layers. Type 2 gossans are related to intrusive rocks cutting the Apsley Formation, and are divided into Type 2a gossans related to biotite-porphyritic or plagioclase-porphyritic metadiabase dikes and into Type 2b gossans related to granite veins and associated quartz veins. Type 2b gossans are best developed in areas where quartz veins predominate over granite veins; the quartz veins generally cut the more thinly bedded parts of the formation. Type 3 gossans occur along Highway 28 and Eel's Creek near Apsley and consist of rusty schist zones in what were probably the more thinly bedded parts of the Apsley Formation in this area. Also, in the area of Type 3 gossans, all parts of the outcrop are rusty-weathering, not only the rusty schist zones, and Type 1 and 2 gossans may also be present. In contrast, Types 1 and 2 gossans are more localized.

About 90 "assay" samples were collected by the author from the Apsley area from all gossan types and analyzed for Au, Cu, Pb, and Zn at the Geoscience Laboratories of the Ontario Geological Survey, Toronto. Table 030.1 summarizes the results. Samples 86RME-160 and 86RME-162 show background levels for the four elements from unmineralized samples. By comparison, Shaw (1972) obtained an average value of 17 ppm Cu from 49 unmineralized samples of the Apsley Formation. Table 030.1 only shows data for samples with anomalous values, or representative samples from each gossan type. Anomalous samples contain >2 ppb Au, >100 ppm Cu, >50 ppm Pb, or >150 ppm Zn for two or more elements. In general, Type 1 gossans show little mineralization (Table 030.1) (1 out of 23 samples), and where some enrichment is present, it is monoelemental. Type 2a and 3 gossans are also not extensively mineralized (2 out of 6 and 0 out of 6

TABLE 030.1: SELECTED ANALYSES FROM APSLEY FORMATION GOSSANS ANALYSES BY GEOSCIENCE LABORATORY, ONTARIO GEOLOGICAL SURVEY

Sample No.	Comment	Au (ppb)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Location (UTM co-ordinate)
86RME-160	background	<2	18	<10	68	E73008,N496089
86RME-162	background	<2	16	<10	118	E72932,N496275
86RME-151	Type 1	<2	42	38	240	E73010,N496088
86RME-152	Type 1	4	20	10	46	E73010,N496088
86RME-161	Type 1	<2	170	<10	112	E72930,N496275
86RME-191	Type 2a	<2	104	<10	190	E73000,N496350
86RME-308	Type 1, 2a	40	31	<10	53	E73000,N496100
86RME-314	Type 2a	<2	45	<10	317	E73000,N496103
86RME-139	Type 2b, Hwy 504	<2	86	13	63	E73106,N495945
86RME-140	Type 2b, Hwy 504	<2	86	91	124	E73106,N495945
86RME-141	Type 2b, Hwy 504	<2	34	16	1170	E73106,N495945
86RME-142	Type 2b, Hwy 504	<2	58	290	220	E73106,N495945
86RME-183	Type 2b	3	38	<10	52	E73130,N496470
86RME-185A	2b, near vein	<2	19	<10	36	E73120,N496425
86RME-185B	Type 2b, vein	7	540	<10	6	E73120,N496425
86RME-198	Type 2b	<2	74	<10	245	E73080,N496270
86RME-337	East Road Gneiss (2b)	75	11	<10	23	E27002,N496103
86RME-215	Type 3	7	13	<10	63	E73027,N495950
86RME-242	Type 3	<2	15	<10	87	E73060,N496040

respectively). Type 2b gossans are most likely to be mineralized (7 out of 25 samples), commonly in more than one element. Sulphide mineralization was probably introduced with the vein material, as shown by sample 86RME-185 in Table 030.1 where the vein material (86RME-185B) is enriched in Au and Cu relative to the host rock adjacent to the vein (86RME-185A). Samples 86RME-139 to 86RME-142 show the highest values for Pb and Zn in the area, and are from a fresh road-cut on Highway 504 on the eastern side of Apsley. On the basis of these results, Type 2b gossans are the most favourable exploration target for precious and base metals in the Apsley Formation.

EXPLORATION GUIDELINES FROM THE PYROCLASTIC FAN FACIES MODEL

Distal facies volcanic sequences are generally less favourable hosts for mineralization than vent/proximal sequences, in part because of the paucity of well developed hydrothermal systems in the distal parts of volcanic edifices (Easton and Johns 1986). However, the same attributes that make turbidite fan systems favourable targets for petroleum exploration, namely the ability of channel systems to serve as conduits and reservoirs for fluids (Walker 1978), have significance with respect to base-metal mineralization within such sequences. Fan channels can serve both as channelways for mineralized fluids, and where capped by finer material, either tuff, muds, or carbonate muds, as sites of deposition. The stratabound character of Type 1 gossans may reflect such controls. Any such mineralization is likely to be laterally extensive, but, depending upon the structural orientation and the erosional cross section through a sequence, such a mineralized channel may have only a limited surface expression. Thus, the most favourable areas of the Apsley Formation for mineralization are where a hydrothermal system was established soon after deposition in the thick-bedded facies of the Apsley Formation, namely the area of relatively poor outcrop exposure west of the Loon Lake pluton between Highway 504 and Chandos Lake (Figure 030.1).

INDUSTRIAL MINERALS

The bulk of the Apsley Formation consists of an attractive, grey to buff weathering, grey stone, uniform in texture and grain size. Within the thick-bedded facies of the Apsley Formation, uniform beds 3 to 10 m thick are common, and could be quarried for building or facing stone. Cleavage is poorly developed in the Apsley Formation, and sulphide mineralization is generally restricted to gossan zones. Fine-grained biotite in the rock is a potential deleterious mineral, but has not caused staining on old road-cut surfaces.

The Dungannon Formation is a well-layered marble, locally with greenish and purplish varieties being present. At Highway 504, a number of fresh outcrops exposed during highway construction illustrate the variety and attractiveness of this stone. The marble does not break preferrentially along bedding surfaces, even during blasting, a common phenonemon in most well layered marbles. Both the Apsley and Dungannon Formations in the Apsley area warrant additional examination for industrial mineral potential.

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031. Geochemical Classification of Archean Volcanic Rocks: Komatiites

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PURPOSE

In February 1985, the Precambrian Section of the Ontario Geological Survey established a committee to investigate methods of geochemical classification for Archean volcanic rocks. Committee members are R.M. Easton (chair), E.C. Grunsky, L.S. Jensen, and P.C. Thurston; J. Howe provided considerable assistance to the committee. The committee was established because of the difficulties that Ontario Geological Survey staff have encountered in applying existing criteria for the geochemical classification of Archean volcanic rocks. In particular, some classification schemes were developed before the recognition of komatiites, or do not include komatiites, and thus exclude a significant group of Archean volcanic rocks. Others do not allow for dependable recognition of alteration in samples. Still others do not readily classify even slightly metamorphosed volcanic rocks, or were developed for use on "fresh" samples only. Finally, there is a philosophical consideration—all existing schemes have been developed for the classification of recent volcanic rocks, with fields being defined by the chemical characterization of modern suites. Historically, Archean rocks have been fitted into these schemes, an approach that could mask chemical signatures of Archean volcanic rocks.

The committee has been charged with the task of developing a classification scheme for Archean volcanic rocks that will be an improvement on existing methods. This task is aided by the large number of geochemical analyses of Archean volcanic rocks that have been acquired at the Ontario Geological Survey over the last decade, and which are incorporated in the PETROCH database. This allows for the evaluation of both classical and statistical classification schemes. This paper is a preliminary report of the committee's work to the time of writing, and outlines its work on the ultramafic-komatiite suite.

What at first may seem to be an academic project has significant application to mineral exploration:

1. Regional correlation of volcanic sequences in the Superior Province relies heavily on chemo-stratigraphic correlation, with mineralization being stratigraphically controlled (Wood and Wallace 1986).
2. Different geochemical groups of volcanic rocks can host different mineralization types (Wood and Wallace 1986).
3. Regional alteration patterns can often be used to delineate potential exploration targets (Wood and Wallace 1986).

A better classification scheme for Archean volcanic rocks will have immediate application to mineral exploration in the Superior Province.

CLASSIFICATION SCHEMES OF VOLCANIC ROCKS

Since volcanic rocks form from magmas that produce minerals of specific and predictable element concentrations, classification schemes based on mineralogy and/or chemistry have been used since chemical analysis of rocks was first implemented. Historically there has been much confusion as to what element, or combination of elements, best classifies volcanic rocks. This confusion is undoubtedly based on the great variety of distinct petrological environments from which volcanic rocks are derived.

Classification schemes that are based upon chemistry have generally assumed that the rock has not been altered. This has been the recommendation of the International Union of Geological Sciences (IUGS) (LeMaitre 1984; Zanettin 1984). As elaborated upon in the section on "Discussion", rocks that have been metamorphosed do not necessarily gain or lose elements, thus chemical classification schemes have been applied to metamorphosed volcanics, but with less certainty. Any volcanic rock that has been altered or metamorphosed where there has been a large amount of water circulation will not have the elements in the same proportions that existed in the rock when it crystallized from a melt. In any case, metamorphosed volcanic rocks cannot be classified by the more conventional methods of crystal composition, form, mineral modes, and flow morphology. Thus, chemical classification becomes one of the few criteria for classification. In the case of the komatiitic rocks the suite is solely defined by chemical parameters.

Middlemost (1972) attempted to classify the modern volcanic rocks on the basis of Si, Na, K, and Al. Irvine and Baragar (1971) classified the common volcanic rocks using normative minerals and chemistry. Viljoen and Viljoen (1969) used Ca, Mg, and Al for discriminating the komatiitic rocks. Jensen (1976) outlined a method of discriminating subalkaline volcanic rocks on the basis of Al, Fe, Ti, and Mg.

The classification scheme of Irvine and Baragar (1971) can be applied to subalkaline and alkaline volcanic rocks and has been developed from analyses of modern volcanic rocks. The classification is, however, heavily dependent on the amounts of Na, and K—two of the most mobile elements in Archean terrains. The classification scheme of Jensen can be applied only to subalkaline volcanic rocks and is well suited to the ultramafic volcanic associations.

Several diagrams have been developed to display the major element trends in volcanic rocks as illustrated in Irvine and Baragar (1971), Jensen (1976), Middlemost (1972), and LeMaitre (1984). These diagrams have been used to display the chemical trends of volcanic rocks using components that are sensitive to compositional variation caused by fractionation. The various volcanic series are empirically defined by crystallization of minerals of differing compositions: there is no one diagram that can display all of the compositional variation within a given series.

The most recent proposal for volcanic classification uses the TAS (total alkalies versus silica) diagram (LeMaitre 1984; Zanettin 1984) and has been proposed by the IUGS. This diagram although useful for fresh, unaltered, and unmetamorphosed volcanic rocks, cannot be applied to volcanic rocks in Archean greenstone belts. The IUGS suggest that fresh volcanic rocks are indicated by: a) $<2\%$ H_2O, and $<0.5\%$ CO_2; and b) the rocks must not be weathered, altered, metasomatized, metamorphosed, or have undergone crystal accumulation. Unfortunately in Archean rocks, some, if not all of these characteristics occur. Sabine *et al.* (1985) discuss the problem of alteration within this system of classification. Further, the TAS diagram does not classify komatiitic rocks in any systematic way, unlike the methods by Viljoen and Viljoen (1969) or Jensen (1976).

CURRENT STUDY

Archean volcanic rocks form four distinct magma associations:

1. ultramafic-komatiitic
2. tholeiitic
3. calc-alkalic
4. alkalic

These associations often form the basis for large scale lithostratigraphic units in greenstone belts. Therefore, a distinction between these groups would aid in stratigraphic and structural correlations within belts.

It is often difficult to classify small numbers of samples because of alteration and metamorphism. However, if the general petrological trend of an area is known, then it might be possible to compare one or more samples with a representative standard. One goal of this project is to define representative standards on the basis of existing lithogeochemical data.

KOMATIITES

KOMATIITE DATABASE

Presently a komatiitic database is being developed in which representative samples from around the world have been included. The database consists of a listing of the chemistry, the source of the information, the outcrop/source description (if available), the age (in this case, all Archean), and locality. The database will be available in the near future as a file that will be useable on MS-DOS/PC-DOS microcomputers. Other files containing data on volcanic rocks from the Archean are being compiled and will include tholeiitic, calc-alkalic, and alkalic rocks, and will be the subject of future reports.

Data for the database was obtained from three sources:

1. Ontario Geological Survey PETROCH database
2. PETROS (Mutschler *et al.* 1975)
3. literature searches

The database of komatiites consists of 1736 samples from the sources listed above. In the field and data sources used in compiling the database, tholeiites and komatiites are associated. Therefore to restrict the original data file of mixed tholeiites and komatiites to just komatiites, the following criteria were used to define komatiites.

For samples recalculated to 100 weight percent (anhydrous):

1. $MgO > 10.0\%$
2. $TiO_2 > 0.2\%$
3. $K_2O < 1.0\%$
4. $SiO_2 < 53.0\%$
5. $L.O.I. < 10.0\%$

These selection criteria reduced the database to 1039 samples. The 1039 samples were then subjected to correspondence analysis and dynamic cluster analysis using 13 chemical components (Si, Al, Fe^{+3}, Fe^{+2}, Mg, Ca, Na, K, Ti, Mn, L.O.I (loss on ignition), Cr, and Ni). The initial analyses indicated that a number of samples were too low in Mg, and too high in Na, K, Ti, and L.O.I. to be considered komatiites. All iron was converted to total FeO which reduced the number of components to 12. These samples were deleted and resulted in a database with 780 analyses which we consider to be representative of komatiitic rocks.

TERNARY DIAGRAMS

Figure 031.1 displays the variation of komatiitic rocks on two commonly used plots. Figure 031.1a shows the compositional variation of komatiitic rocks on the CaO-MgO-Al_2O_3 weight percent diagram used by Viljoen and Viljoen (1969). Figure 031.1b shows the compositional variation of komatiitic rocks on the Al-Fe+Ti-Mg cation percent diagram developed by Jensen (1976). These figures display 780 samples selected from the database. Only the least altered or properly classified rocks were used on these plots. Many of the komatiites are carbonatized, or are tholeiites that have been misclassified as komatiitic rocks.

Both diagrams in Figure 031.1 display trends that typically define the komatiitic series. In Figure 031.1a there is the main trend of compositional variation that defines the transition from komatiites to basaltic komatiites. Although Viljoen *et al.* (1982) indicate that there are clear discontinuities in the data that define the various komatiitic rock types, this is not apparent on Figure 031.1a. This is probably due to the geographic diversity of samples and the wide range of alteration/metamorphic effects that are represented in the sample population.

Viljoen and Viljoen (1969) used the diagram of Figure 031.1a to discriminate komatiites from other ultramafic and mafic rocks based on the fact that their komatiites had CaO/Al_2O_3 ratios of ≥ 2.0. Subsequent studies (Nesbitt and Sun 1976; Nesbitt *et al.* 1979) indicate the range of CaO/Al_2O_3 to be ≤ 0.9 to ≥ 2.0, and that these rocks have chemical characteristics that overlap with tholeiitic rocks. The ratios of 2.0 and 1.0 are shown in Figure 031.1a and it can be

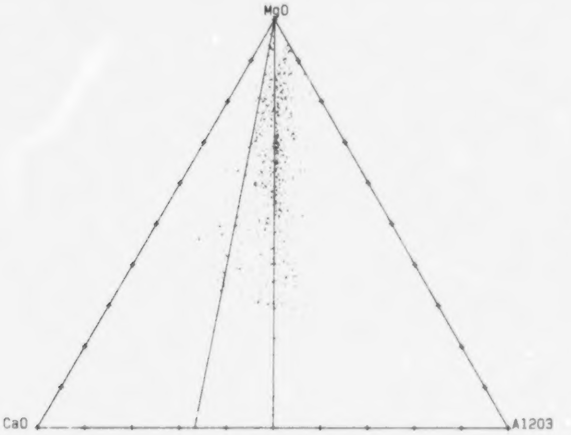

Figure 031.1a. *CaO-MgO-Al_2O_3 weight percent diagram of the komatiite database (780 samples).*

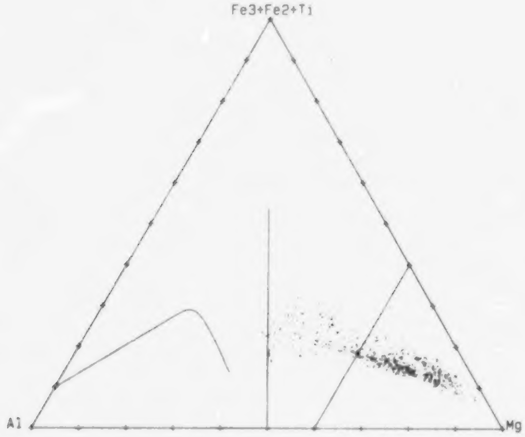

Figure 031.1b. *Al-Fe+Ti-Mg cation diagram of the komatiite database (780 samples).*

seen that most of the komatiites fall into a trend of CaO/Al_2O_3 of ≤ 1.0.

Figure 031.1b shows a continual transition from komatiites to tholeiites on the Al-Fe+Ti-Mg diagram of Jensen (1976).

Although these diagrams are based on critical chemical ratios within the komatiitic suite, secondary processes can alter the ratios of these critical components and thus displace the sample projection on the diagram. Also, within a suite of igneous rocks, chemical variation may be controlled by a number of elements, and a simple binary or ternary diagram may not reveal secondary processes that have altered the ratios of the components.

Multivariate analysis is able to specify the principal chemical components involved in variation within an igneous suite. Systematic chemical variability based on different igneous or alteration/metamorphic processes can be readily distinguished from each other. This approach has been used by LeMaitre (1976).

Two statistical methods of determining distinct chemical trends within a sample population of igneous geochemical data are correspondence analysis and dynamic cluster analysis. A discussion of correspondence analysis is given in Davis (1986) and David *et al.* and dynamic cluster analysis is described and discussed by Diday (1973) and Lefebvre and David (1977). David *et al.* (1974), Teil and Cheminee (1975), and Grunsky (1986) have shown that these methods can delineate trends and distinguish between groups of rocks whose chemistries are statistically distinct from each other.

CORRESPONDENCE ANALYSIS

Comparison between a number of samples with analytical data for 15 elements (i.e. 15 dimensions) is a difficult task. If the number of distinguishing criteria can be reduced from 15 to 5, then comparison between the samples would be much easier. The principle behind factor analysis is to represent the data in terms of a number of axes (factors) that describe the distribution of the data in fewer dimensions than the original data. Each factor can be thought of as describing a geological process. These geological processes include primary processes such as differentiation (partial melting, crystal fractionation, etc.) as well as secondary processes that include alteration (carbonatization, silicification, alkali depletion, etc.). In a suite of unaltered volcanic rocks there is generally an inverse relationship between [Na, K] and [Ca, Mg, Fe]. If the data distribution were governed only by those components, the compositional variation would be dominantly along one axis illustrating a differentiation trend (i.e. Harker diagrams). However, if the rocks within a given suite have been altered by some process such as carbonatization, then not only are the data distributed along a direction defined by its petrogenesis, but also along an axis that describes the departure of the data from an igneous trend by one or more components associated with the alteration process (for example CO_2). In correspondence analysis the factors are calculated from a matrix comprised of columns of chemical components and rows of samples. The factors are determined by the computation of eigenvalues that represent a systematic distribution of the data based on component abundances.

Table 031.1 lists the components used in the correspondence analysis, as well as the mean values for each element. Note the high L.O.I. (5.69%). Table 031.1 also lists the computed eigenvalues and the contribution of each eigenvalue. The first eigenvalue accounts for 69.25% of the data variation and the first five eigenvalues account for 94.24% of the total variation in the data. The first two factors are the most significant in terms of the variation of the data, and interpretation of each factor should take into account how much of the data variation each factor represents.

Table 031.2 lists the factor scores of the components. It can be seen that in Factor 1, Mg, Cr, and Ni all have high positive factor scores, while Na, K, Al, and Ti all have negative scores. Thus, the inverse

TABLE 031.1: MEAN VALUES, EIGENVALUES, AND CONTRIBUTIONS.

	Mean Values (Weight %)	Eigenvalues	% of Contribution
Si	45.09	0.07282255	69.27
Al	6.72	0.01000872	9.52
Fe	10.89	0.00697761	6.64
Mg	22.64	0.00506100	4.81
Ca	7.17	0.00420909	4.00
Na	0.61	0.00216886	2.06
K	0.10	0.00187762	1.79
Ti	0.47	0.00082432	0.78
Mn	0.18	0.00061281	0.58
LOI	5.69	0.00043137	0.41
Cr	0.30	0.00013049	0.12
Ni	0.14		

LOI - Loss on ignition

TABLE 031.2: FACTOR SCORES OF THE VARIABLES.

Variable	1	2	3	4	5
Si	-0.0829	-0.0162	-0.0107	0.0192	0.0057
Al	-0.3447	0.1960	-0.0743	-0.0532	-0.1626
Fe	-0.0512	0.0420	-0.0165	-0.1452	0.1099
Mg	0.3487	-0.0790	-0.0414	0.0036	-0.0323
Ca	-0.4599	-0.1332	0.1946	0.0358	-0.0149
Na	-0.8688	0.1771	-0.5273	0.5389	0.3282
K	-0.5805	0.1717	-0.0036	0.0695	-0.1247
Ti	-0.4074	0.0724	-0.0005	-0.1143	0.1274
Mn	-0.0990	0.0348	0.0530	-0.1020	0.0686
LOI	0.4665	0.2711	0.1728	0.0880	0.0372
Cr	0.2724	-0.0316	0.0854	-0.0741	-0.0261
Ni	0.5588	0.0347	0.0436	-0.0607	0.0991

LOI - Loss on ignition

relationship between these components are expressed.

Table 031.3 lists the contributions of each component to each factor (actual contribution (AC)). Si contributes 4.25% of the variation accounted for by Factor 1. The distribution of how each component is distributed over the first five factors is indicated by the relative contribution (RC). Note that 89.73% of Si variation is accounted for by the first factor.

The first factor (first eigenvalue 69.25%) is dominated by the variability of Mg, Ca, L.O.I., and Al. Therefore, these components control most of the variability of the data. Over 80% of the variation of Si, Mg, Ca, K, Ti, Cr, and Ni is accounted for in the first factor, indicating that although these components do not vary as greatly as Mg, Ca, Al, and L.O.I., their distribution is possibly controlled by the same processes. Since much of the variation is within the first factor, this suggests that a single process controls the distribution of the components. The second factor (9.52%, second eigenvalue) is dominated by the variability of L.O.I. Al. Mg. and Ca (*see* Table 031.3). These components represent variation due to other processes which might include plagioclase fractionation (Ca, Al variation), or alteration (Mg, L.O.I.).

The third factor (6.64%, third eigenvalue) is dominated by the variation of Ca, Na, and L.O.I., and possibly represents alteration (L.O.I.), plagioclase enrichment (Ca), or metasomatism (Na).

The fourth factor (4.84%, fourth eigenvalue) is dominated by Fe and Na. A significant amount of Mn (35.95% RC) is also accounted for in the fourth factor. This suggests that Fe-controlled fractionation might be a contribution to the variation of the data. The prominence of Na probably represents metasomatized Fe-enriched rocks.

The fifth factor (4.0%, fifth eigenvalue) is dominated by Al, Fe, and Na. Note also that a significant amount of Mn is accounted for in the fifth factor. Similarly, the presence of Na (15.59% AC) probably represents metasomatized rocks.

TABLE 031.3: CONTRIBUTIONS OF THE VARIABLES TO THE DATA VARIATION.

	Absolute and Relative Contributions									
	AC(1)	RC(1)	AC(2)	RC(2)	AC(3)	RC(3)	AC(4)	RC(4)	AC(5)	RC(5)
Si	4.26	89.84	1.19	3.44	0.73	1.48	3.28	4.81	0.35	0.43
Al	10.96	61.87	25.77	20.00	5.32	2.88	3.75	1.47	42.20	13.77
Fe	0.39	6.93	1.92	4.66	0.42	0.72	45.34	55.75	31.25	31.95
Mg	37.81	93.09	14.13	4.78	5.57	1.31	0.06	0.01	5.62	0.80
Ca	20.82	78.74	12.71	6.61	38.90	14.10	1.81	0.48	0.38	0.08
Na	6.31	51.61	1.91	2.14	24.28	19.02	34.96	19.86	15.59	7.37
K	0.47	87.11	0.30	7.62	0.00	0.00	0.10	1.25	0.38	4.02
Ti	1.06	82.77	0.24	2.61	0.00	0.00	1.21	6.52	1.80	8.09
Mn	0.02	33.90	0.02	4.19	0.07	9.71	0.37	35.95	0.20	16.25
LOI	17.00	65.93	41.76	22.26	24.35	9.05	8.71	2.35	1.87	0.42
Cr	0.30	83.69	0.03	1.12	0.31	8.22	0.32	6.20	0.05	0.77
Ni	0.58	94.95	0.02	0.37	0.04	0.58	0.10	1.12	0.32	2.98

AC - Absolute Contribution: % contribution to the factor
RC - Relative Contribution: % contribution over the 5 factors

It is important to note the significance of the factors when interpreting the data. The third, fourth, and fifth factors account for only 15.48% of the data variation which is small relative to the first two factors that contribute to 78.77% of the data variation. Thus the Fe, Na, and L.O.I. that are accounted for by the lesser factors do not have the same significance as Mg which is accounted for by the first factor.

Each sample can be plotted onto a projection in factor space so that the relationship between samples and components can be examined. Figure 031.2a shows the samples and component factor scores projected on the the Factor 1—Factor 2 (F1-F2) plane.

As pointed out previously, Factor 1 represents the variation in the data, probably due to major fractionation processes. Along the positive end of the F1 axis, the samples that represent the most mafic rocks plot near the factor score projections of Cr, Ni, and Mg. At the negative end of the F1 axis, rocks enriched in Ca, Ti, Al, and Na plot near these components. The samples associated with the positive end of F1 are the most ultramafic rocks, while those at the negative end of the axis represent a fractionation trend toward basaltic komatiites and tholeiitic basalts (increased Ca, Ti, and Al). Note that L.O.I. is mainly associated with the ultramafic end. This is probably due to the ease which ultramafic rocks are carbonatized relative to tholeiitic rocks. Dispersion of the data along the F2 axis is determined by the variation of L.O.I., Ca, and Al. Samples that plot on the negative side of the F2 axis tend to be Ca enriched and samples that plot toward the positive end of F2 tend to be Al and L.O.I. enriched.

Similarly, Figure 031.2b shows the projection of the factor scores on the F1-F3 projection. It can be seen that dispersion along the F3 axis could be due to Ca enrichment along the positive side (plagioclase fractionation) and Na enrichment along the negative side (metasomatism). Figure 031.2c (F1-F4 plane) shows the Na-enriched rocks associated with positive Factor 4 scores and Fe-Mn enrichment associated with negative scores.

In Figure 031.2d (F1-F5 plane), positive F5 scores represent Na-, Fe-, and Mn-enriched rocks, and negative scores represent K- and Al-enriched rock.

DYNAMIC CLUSTER ANALYSIS

Within the distribution of the data in factor space, it can be seen that several "clouds" or groups of sample points occur (Figures 031.2 to 031.4b). Some of these groups have an obvious geological interpretation, such as those relating to Mg, Cr, and Ni enrichment or alteration (increased volatiles). It is difficult however to "see" some groups of points that may occur along the factor axes because projection onto a two-dimensional plot for visual presentation will obscure groups. A technique for detecting groups of points in n-dimensioned space is that of dynamic cluster analysis (Diday 1973; Lefebvre and David 1977).

The dynamic cluster analysis method works by grouping samples closest to randomly chosen nucleii (i.e. points) in factor space derived from the correspondence analysis. By iteration, the locations of nucleii are refined until the locations no longer change and the nucleii represent centres of sample groups.

Table 031.4 lists the average compositions of each component for each group, as well as the coefficient of variation (C.V.). The coefficient of variation represents the standard deviation as a percentage of the mean.

Figure 031.4a shows the positions of each group projected on the F1-F2 plane, and Figure 031.4a shows the groups on the CaO-MgO-Al_2O_3 plot, and the Al-Fe+Ti-Mg Jensen plots, respectively.

Below is a description of the groups determined by the cluster analysis. Some interpretation is provided; however, the authors are still investigating the significance of the groups. Some of the groups may have no petrological significance.

Group 1 plots in the komatiite field in both the Al-Fe+Ti-Mg Jensen plot, and the CaO-MgO-Al_2O_3 plot.

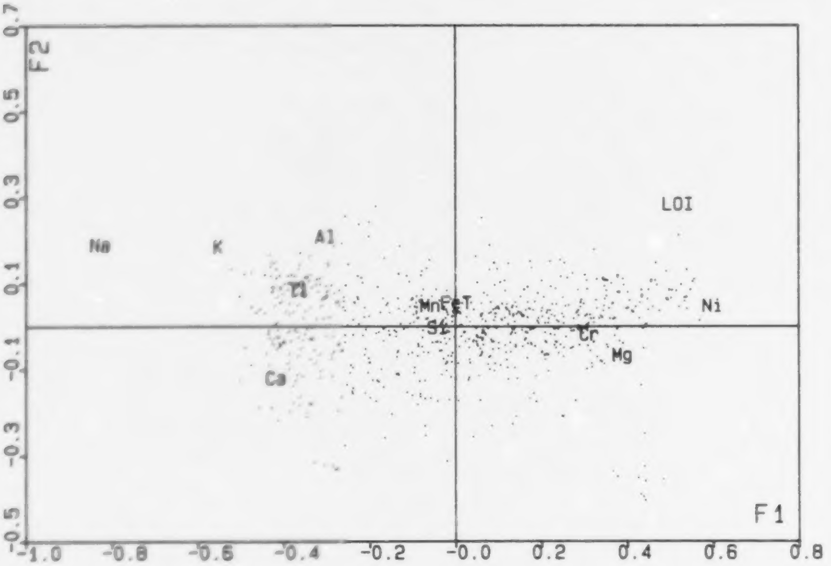

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Figure 031.2a. *F1-F2 projection of the sample and variable factor scores.*

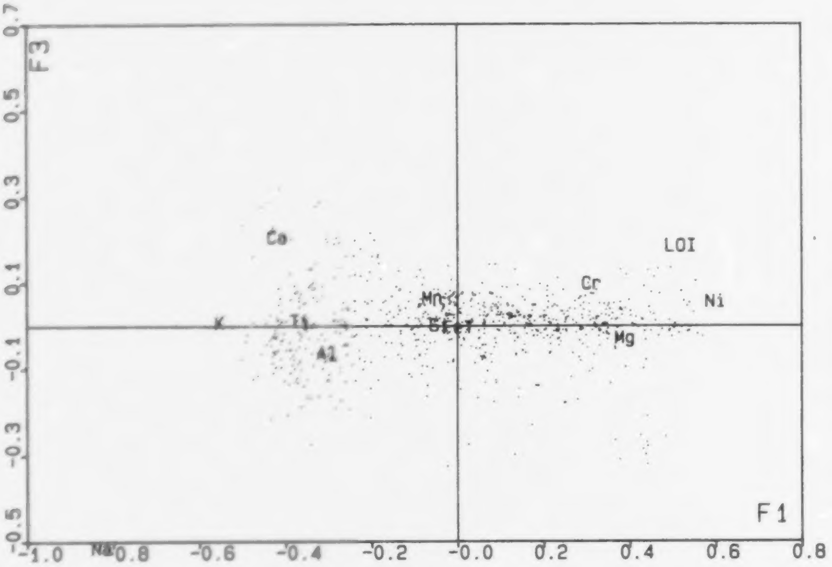

Figure 031.2b. *F1-F3 projection of the sample and variable factor scores.*

On the F1-F2 projection, this group plots in the centre of the factor space, and represents an average composition of the entire database that was used in the analysis. This group is neither Mg-Cr-Ni-enriched, nor Ca-Al-Ti-enriched relative to the entire population of samples.

Group 2 is similar to Group 1 in that it represents komatiites, however it is slightly more Mg-enriched relative to Group 1. Group 1 has a slightly higher Na content than Group 2 and this may explain the statistical uniqueness of the two groups. On the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plot (Figures 031.4a and 031.4b) these samples plot in the komatiitic fields, and on the F1-F2 projection of the factor space these samples plot toward the Mg-Cr-Ni-enriched rocks.

Group 3 is decidedly more Mg-Cr-Ni-enriched and plots well into the komatiitic fields of both the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plot. Compositionally this group has an average Ca/Al ratio of 0.58, and an average composition of 33% MgO, 3500 ppm Cr, and 1600 ppm Ni. Samples in this group include intrusive ultramafic rocks from the Dundonald area in Timmins, and other cumulate phases in komatiitic flows and intrusives. Many samples are labelled as flow cumulates or peridotitic flows. Thus, many cumulate phases are distinct with high Cr-Ni-Mg contents and low Ca/Al ratios. A high volatile content is also associated with these samples (Table 031.4). The first three groups account for 46% of the samples used in the analysis.

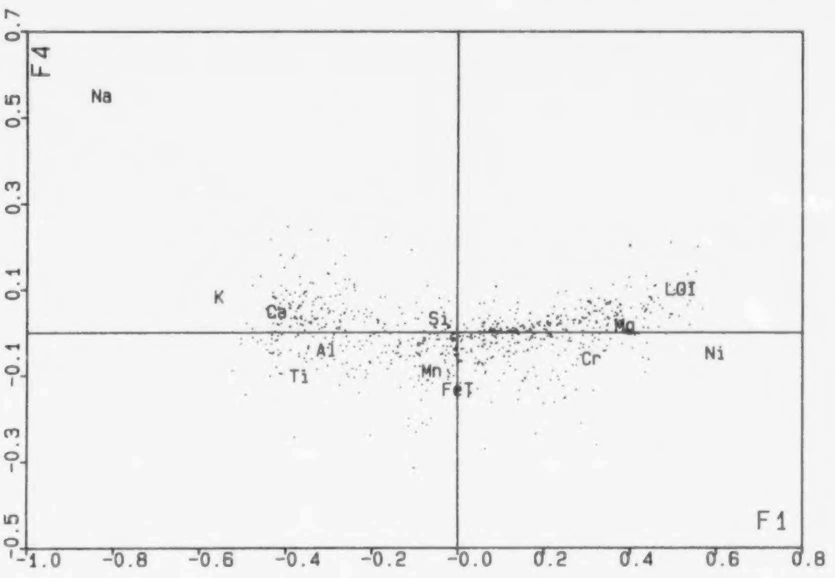

Figure 031.2c. *F1-F4 projection of the sample and variable factor scores.*

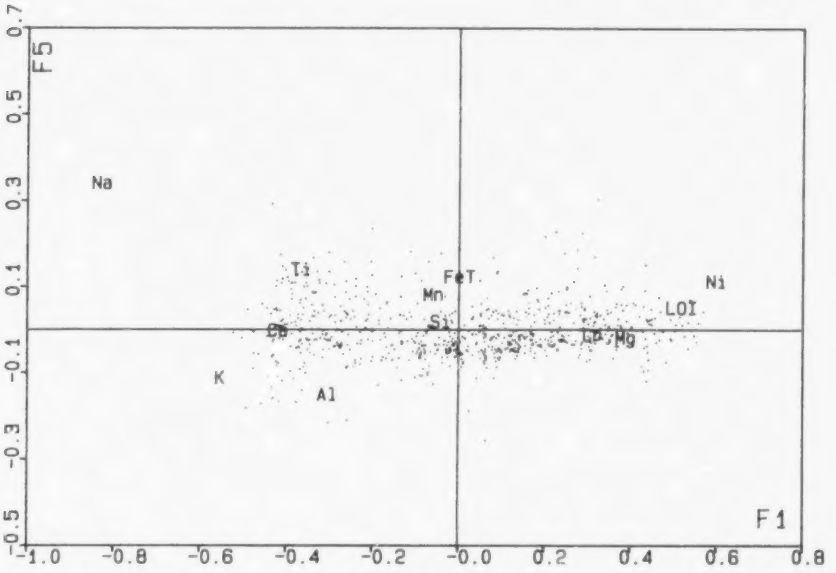

Figure 031.2d. *F1-F5 projection of the sample and variable factor scores.*

Group 4 represents a diffuse group of samples on the F1-F2 projection, and also plots within the komatiitic fields of the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plot. These samples are low in volatiles and represent relatively unaltered komatiites.

It should be noted that Groups 1 through 4 have average MgO compositions of >18% and thus fit within the definition of Arndt and Nisbet (1982).

Group 5 samples project toward tholeiitic compositions as shown in the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plot. This group also plots toward Ti-Al-Ca enrichment on the F1-F2 projection. Many of these samples are described as containing plagioclase, augite phenocrysts, and are classified as high-Mg basalts. The Al composition is significantly high (12.86%); Mg is 9.84%, Na is 1.49%, and Cr and Ni are low. The rocks of this group occur within komatiitic sequences and most probably represent fractionated komatiitic flows.

Group 6 is characterized by Ti-Ca-Al enrichment and represents basaltic komatiites on the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plot. The samples have been described in the original sources as basaltic komatiites, olivine cumulate basalts, high Mg basalts from the Barberton Mountains area, and pyroxenitic komatiites. Group 7 is similar in composition to Group 6 however it is higher in Na, and may represent regionally metasomatized rocks.

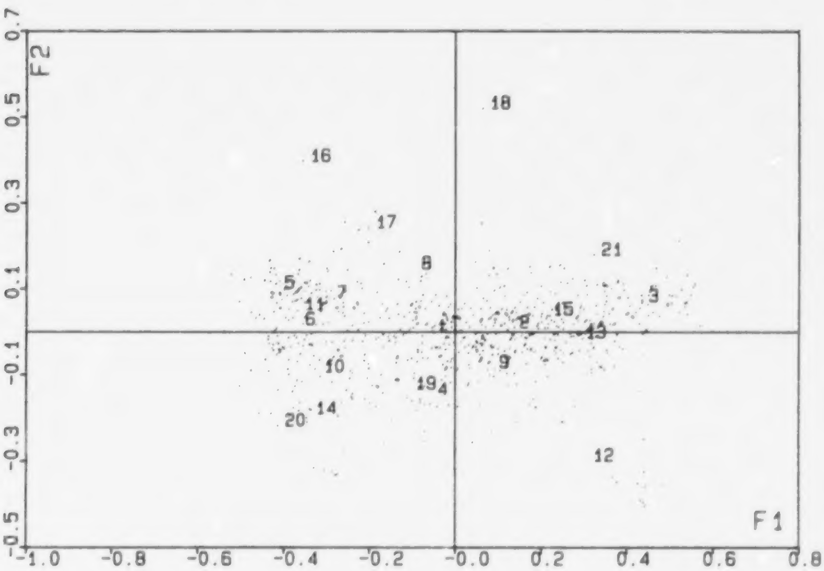

Figure 031.3. F1-F2 projection of the group locations as determined from the dynamic cluster analysis.

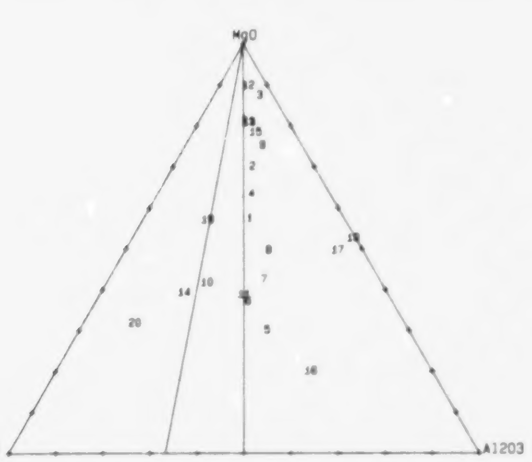

Figure 031.4a. CaO-MgO-Al_2O_3 weight percent diagram of the group averages from the dynamic cluster analysis.

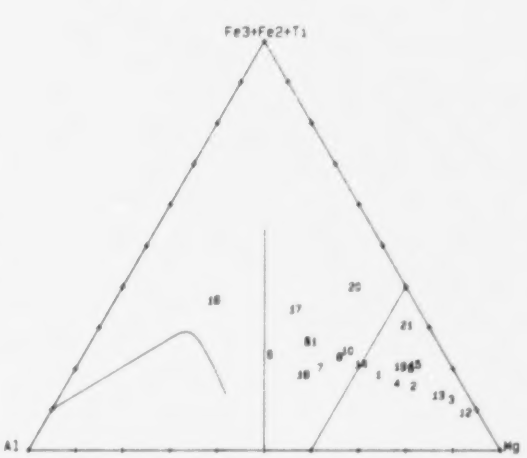

Figure 031.4b. Al-Fe+Ti-Mg cation diagram of the group averages from the dynamic cluster analysis.

Group 8 is a diffuse group on the F1-F2 projection but tends to plot near groups that are basaltic komatiite in composition. This group is distinct because of its higher Fe content than most basaltic komatiites. This could be due to the presence of sulphur. The samples in this group are from a wide range of lithologies and rock types.

Group 9 is a group with samples which are low in Al and Ca, and high in Mg and Fe. This group plots within the komatiitic fields of the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plot, but with a large scatter. This group is similar in composition to Groups 1 and 2, but has a less volatile content.

Group 10 is Ca-Ti-enriched with a Ca/Al ratio of 1.87. The group is diffuse on the F1-F2 projection as well as on the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plots. Group 11 represents Na-enriched basaltic komatiites. Group 12 is an extremely Mg-enriched group, all from the Dharwar region of India. These rocks are metamorphosed peridotites and amphibolites, and low in volatiles, Cr, and Ni.

Group 13 consists of Cr-enriched komatiitic rocks and plot as a closely clustered group on both the Al-Fe+Ti-Mg Jensen plot and the CaO-MgO-Al_2O_3 plots. Group 14 is a group of Ca-enriched, L.O.I.-poor, and Al-poor komatiitic rocks. Ca-rich pyroxene may be a significant phase in these rocks.

Group 15 represents Fe-enriched rocks relative to Group 3. This may indicate that this group contains more Fe in the olivine. This group is lower in volatiles relative to Group 3. Group 19 represents Ca-, and Na-enriched samples in the komatiite-basaltic komatiite fields. These are probably altered samples.

TABLE 031.4: AVERAGE COMPOSITIONS (WEIGHT %) AND COEFFICIENT OF VARIATION (C.V.) OF EACH GROUP.

Group	Si	C.V.	Al	C.V.	Fe	C.V.	Mg	C.V.	Ca	C.V.	Na	C.V.
1	45.30	4.95	7.76	18.85	11.08	11.18	20.88	14.16	8.16	18.15	0.44	83.30
2	43.95	6.35	5.95	19.78	10.58	9.68	26.81	7.03	5.90	19.54	0.20	105.82
3	38.38	8.13	3.23	28.12	9.19	20.76	33.51	7.52	1.90	65.93	0.07	167.06
4	45.63	5.22	7.09	21.77	10.39	7.97	24.06	10.65	7.22	13.02	0.27	130.03
5	50.31	2.59	12.86	9.59	10.91	12.88	9.84	15.09	10.78	10.62	1.49	26.25
6	49.22	4.63	10.07	11.02	12.80	11.15	11.88	16.98	10.68	17.01	1.41	32.96
7	50.03	4.76	10.39	13.55	9.82	17.60	13.70	14.80	8.75	15.96	2.05	20.08
8	43.05	6.19	9.75	25.51	12.96	20.10	16.45	32.95	7.44	30.83	0.25	151.43
9	42.84	9.27	5.25	47.22	13.86	19.65	26.17	22.18	3.68	51.76	0.38	182.90
10	50.77	3.78	6.86	14.60	10.93	14.22	13.68	13.39	12.85	11.19	1.27	37.32
11	51.48	3.95	8.75	17.27	11.78	14.51	11.21	10.04	9.42	16.97	2.83	18.46
12	43.08	12.62	2.50	88.06	7.72	23.45	41.01	21.08	2.52	68.32	0.79	46.73
13	42.47	6.54	3.96	28.47	9.73	18.03	31.63	7.83	3.87	35.21	0.12	107.22
14	48.59	5.49	6.33	35.81	9.16	20.40	14.47	22.40	16.70	11.57	0.41	81.29
15	41.14	7.19	4.33	27.77	14.62	13.14	26.71	8.65	3.32	25.72	0.12	119.67
16	49.99	0.00	14.31	0.00	16.34	0.00	5.19	0.00	7.29	0.00	1.65	0.00
17	43.74	0.00	10.19	0.00	18.04	0.00	11.20	0.00	1.55	0.00	0.97	0.00
18	27.46	0.00	20.21	0.00	15.27	0.00	22.66	0.00	0.87	0.00	0.05	0.00
19	48.08	4.93	4.62	27.72	11.01	17.59	19.95	17.03	10.86	12.55	0.38	65.86
20	44.45	0.00	3.50	0.00	16.13	0.00	10.70	0.00	20.20	0.00	0.40	0.00
21	27.46	0.00	2.65	0.00	20.23	0.00	22.18	0.00	2.76	0.00	0.03	0.00

TABLE 031.4: Continued

Group	K	C.V.	Ti	C.V.	Mn	C.V.	L.O.I.	C.V.	Cr	C.V.	Ni	C.V.
1	0.08	162.12	0.46	37.32	0.19	18.85	5.05	23.27	0.36	34.58	0.11	36.10
2	0.12	146.30	0.35	30.24	0.17	19.45	7.46	16.96	0.35	28.58	0.16	33.66
3	0.02	132.82	0.22	43.67	0.15	61.02	11.71	11.99	0.40	69.34	0.27	38.51
4	0.06	121.09	0.44	27.32	0.17	34.62	1.06	119.05	0.36	45.18	0.14	36.02
5	0.31	82.49	0.68	34.25	0.19	20.49	2.61	38.30	0.09	59.60	0.02	59.51
6	0.16	58.95	0.91	39.01	0.22	27.92	1.78	70.86	0.15	53.31	0.04	62.21
7	0.15	106.68	0.60	24.36	0.18	17.40	3.58	30.14	0.22	40.45	0.06	65.04
8	0.08	239.65	0.57	38.62	0.20	18.71	6.88	21.65	0.22	74.93	0.08	68.89
9	0.07	155.41	0.46	62.56	0.20	40.32	2.73	93.12	0.40	62.89	0.17	62.51
10	0.14	91.85	0.71	26.47	0.19	33.96	2.20	57.32	0.18	47.33	0.04	38.39
11	0.15	96.61	0.68	31.00	0.19	32.01	2.60	45.49	0.14	38.09	0.04	71.75
12	0.06	75.66	0.15	83.09	0.05	136.06	1.22	90.68	0.14	44.18	0.13	62.99
13	0.04	104.97	0.25	32.54	0.16	24.23	8.61	13.40	0.36	41.06	0.21	42.26
14	0.23	161.86	0.64	52.97	0.19	23.86	1.89	89.33	0.22	73.37	0.04	60.29
15	0.02	139.32	0.46	67.21	0.21	21.17	7.72	16.82	0.35	58.87	0.27	56.44
16	0.95	0.00	1.96	0.00	0.39	0.00	8.64	0.00	0.03	0.00	0.00	0.00
17	0.47	0.00	1.27	0.00	0.17	0.00	3.34	0.00	0.00	0.00	0.00	0.00
18	0.01	0.00	1.18	0.00	0.17	0.00	10.14	0.00	0.00	0.00	0.06	0.00
19	0.05	91.02	0.47	43.99	0.21	26.31	3.74	38.48	0.26	48.38	0.09	57.15
20	0.28	0.00	0.95	0.00	0.22	0.00	2.02	0.00	0.32	0.00	0.16	0.00
21	0.00	0.00	0.13	0.00	0.17	0.00	10.00	0.00	0.44	0.00	1.27	0.00

Groups 16, 17, 18, 20, and 21 are single samples that have no significance as groups.

DISCUSSION

Komatiite fractionation is dominated by olivine crystallization. The suite of rocks associated with komatiites includes the extremely Mg-rich olivine cumulates and the more evolved basaltic komatiites resulting from increasing plagioclase and clinopyroxene crystallization. Complications in interpretation of the patterns and groups can arise from the uncertainty of the processes that have acted to form the present chemistry of the rock.

The nature of the compositional variation that reflects primary geological processes can be difficult to interpret. Some komatiitic magmas may be enriched in the more incompatible elements with respect to the olivine crystal lattice. Ti, Mn, Al, Fe, Na, and K can be enriched in some of the komatiitic rocks due to assimilation en route to the surface. These characteristics show up as less significant factors and may account for Factors 3, 4, and 5. Further investigation is required.

Processes such as alteration and metamorphism have an effect on the compositions that result in a variety of changes. During low grade metamorphism, H_2O is commonly added to the rock, and there is a redistribution of Fe, Mg, and the alkalis within a given volume of rock. As metamorphism increases, to greater than greenschist facies, the H_2O content of the rock decreases and in regional metamorphic events there is an introduction of Na, K, or both.

Alteration associated with hydrothermal systems usually results in an increase of CO_2. The alkalies and Mg are the most readily transported species in hydrothermal and metamorphic fluids and typically the oxidation state of iron is readjusted. Generally, Al, Ti, Si, Mn, P, S, Cr, and Ni are not less mobile in these systems.

Low grade metamorphic reactions and hydrothermal systems are where most of the element mobility occurs, or where the systems are the most "open". Since the chemistry of the volcanic rocks is based on a systematic distribution of elements through crystallization, any change in the equilibrium of the system will result in an apparent imbalance of elements relative to the unaltered primary chemistry. As long as the water:rock ratio is low, there is no significant alteration. The migration of fluids and the distance that the fluids travel defines the degree of "openness" of the system, with the resulting addition and depletion of elements. With these concepts in mind, the interpretation of ternary diagrams, factor scores, and clustered groups of samples must be done with careful consideration. Both the CaO-MgO-Al_2O_3 and the Al-Fe+Ti-Mg ternary plots (Figures 031.1 and 031.4a) show the main fractionation trends but they do not show any features of alteration/metamorphism. The multivariate approaches discussed above not only outline the main fractionation trends, but also show how the chemical component abundances are related to each other (i.e. Ca and Mg are inversely related). The correspondence analysis method indicates that although most of the variation of the data is related to what appears to be one process (the first eigenvalue which accounts for 69.25% of the data variation), it also shows which samples follow other trends, trends that are related to alteration and other geological processes. The samples that represent these trends may be altered/metamorphosed komatiitic rocks, or they may have been originally misclassified.

The use of multivariate techniques is an effective tool for examining all aspects of the chemistry of volcanic rocks. The graphical technique of projecting the factor scores of the samples and the chemical components onto the principal axes projections permits examination of the relationships between the samples and the components. In these diagrams, not only can the relationship between the chemical components that represent the primary geological processes be observed, but also the departures from the main trend which indicate secondary processes, some of which are related to alteration. The identification of these secondary trends can be useful when examining lithogeochemical data for possible exploration targets.

Components that are related to each other form common factors and thereby reduce the number of dimensions necessary to examine the data. In particular, the use of the dynamic clustering method allows for objective classification of a multicomponent population and calculates how each group is distinct by calculating average compositions for each group.

Within this preliminary investigation of the komatiitic database it can be seen that alteration of Archean komatiitic rocks plays a major role in their chemistry and should not be ignored. It is planned that this database, and future databases being developed, will assist, not only in the detection of primary compositional variation in Archean greenstone belts, but also in detecting alteration associated with metasomatism and with associated mineral deposits. Further work is being carried out to achieve these goals.

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032. Geological Software for Personal Computers

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INTRODUCTION

During the past year, the Precambrian Geology Section of the Ontario Geological Survey has modified its package of computer programs for use on IBM Personal Computers or compatibles. Three main packages of programs are available dealing separately with geochemical, structural, and field note data. The programs either list results on a printer, draw diagrams on a plotter, or both. The next step in program development will be the capability of drawing diagrams on the screen in addition to being able to draw diagrams on the plotter. The following is a list of all the programs currently available. These programs were previously described in the Summaries of Field Work by the Ontario Geological Survey for 1984 and 1985 (Ambrose *et al.* 1984; Ambrose and Wright 1985) with the exception of the program STRUCSYM which is new.

BINARY

BINARY produces X-Y diagrams according to predefined formulae or user-defined formulae. The program allows the user to define the type and length of the axes, the label for the axes, the title of the plot, the style and colour of the points, and the scaling of the plot. A best-fit curve may be generated using least squares regression analysis. User-defined formulae may contain major oxides, trace elements, Barth-Niggli (Barth 1959) normative minerals, or CIPW normative minerals (*see* Figure 1a).

CHONDRITE

This program draws chondrite-normalized (Hanson 1980) rare earth element plots. Up to seven samples may be plotted on each diagram and each sample is drawn using a different colour and symbol. A legend is produced defining the plotted symbols by sample numbers, comments, or both (*see* Figure 1b).

DENSITY

DENSITY calculates the densities of liquid silicate systems from whole rock analyses following the method of Bottinga *et al.* (1982). The density calculations are based on partial molar volumes of the oxide components. The user has a choice of the $FeO/Fe^{2}O^{3}$ratio and, if water is to be included in the calculations, a choice of the pressure. The final temperature used in the density calculation may either be entered by the user or determined based on the MgO number (MgO number = anhydrous molecular proportion of MgO divided by the sum of MgO and FeO anhydrous molecular proportions).

NECRETREV

NECRETREV allows the user to retrieve information from field note data files. The field note format created by Greg Stott and Eric Grunsky of the Ontario Geological Survey (Ambrose *et al.* 1984) combines numeric codes for observed features with the capacity to add unlimited descriptive text. The user selects a category number, for example that for mafic volcanic rocks, and the program retrieves all stations at which mafic volcanic rocks were found along with any notes taken about these rocks.

NECSTRUCT

This program retrieves structural data from field note data files (*see* NECRETREV above). When a category number for the desired structural feature is entered by the user, the strike and dips or azimuth and plunges for all the stations containing the feature are then used to create a new computer file. This new file may then be used to draw stereonets (*see* STRNET below).

QAPF

QAPF draws quartz-alkali feldspar-plagioclase feldspathoid diagrams following the modal classification scheme of Streckeisen (1976). The quaternary diagram is divided into twenty-six regions by category boundary lines. The user has a choice of the title of the plot, and the style and colour of the points (*see* Figure 1c).

SAMPLOT

This program plots sample locations at 1:50 000 or 1:15 840 scale. The style, colour, and method of labeling for the points is user defined. Either a UTM grid or border may be drawn (*see* Figure 1d).

STRNET

STRNET draws equal area (Schmidt) stereonet projections of either planar or linear data. The radius of the net, the title of the plot, and the style and colour of the points are user defined (*see* Figure 1e).

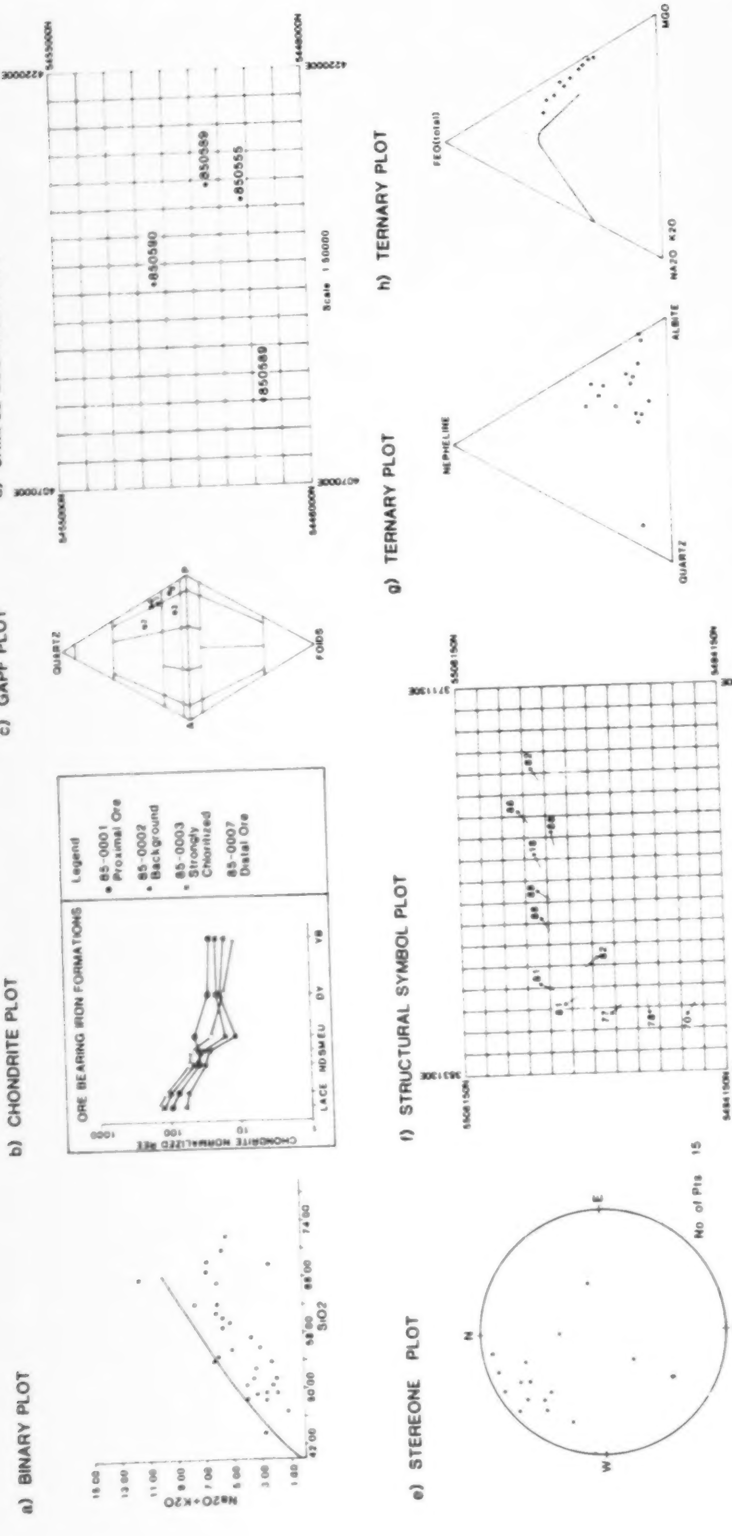

Figure 032.1. Sample diagrams produced by the programs: (a) BINARY; (b) CHONDRITE; (c) QAPF; (d) SAMPLOT; (e) STRNET; (f) STRUCSYM; and (g,h) TERNARY.

STRUCSYM

This program plots structural symbols from a field note file (*see* NECRETREV above) on a 1:50 000 or 1:15 840 scale. Each feature is drawn using a different symbol and colour. The user has a choice of the scale, the feature(s) to be plotted, whether all occurrences of the feature at each station are to be plotted, whether the plunge and/or dip values are to written, the title of the plot, and the location of the grid (*see* Figure 1f). The choice of features to plot are:

bedding plane
bedding plane and sedimentary striations on bedding planes
mineral foliations and/or mineral lineations
gneissosity
cleavage
crenulation lineation
bedding/cleavage intersection lineation
fold axis, axial plane, and type of fold
fault plane and slickensides
shears and slickensides
joints

TERNARY

This program draws ternary diagrams with either predefined or user-defined apices. The title of the plot, and the style and colour of the points are user-defined. The predefined plots are:

1. Jensen cation diagram ($Fe^3+Fe^2+Ti+Mn$—Al—Mg) (after Jensen 1976, and Grunsky 1981)
2. quartz-alkali feldspar-plagioclase diagrams (QAP) (after Streckeisen 1976)
3. Na^2O+K^2O—FeO (total)—MgO diagrams (AFM) (after Thompson 1957)

The user-defined plots may contain major oxides, trace elements, Barth-Niggli normative minerals, or CIPW normative minerals (*see* Figures 1g and 1h).

SUMMARY

These programs are written in Professional Fortran 77 and use an Industry Standard Plotting Package for a Hewlett Packard 7220C. Source listings, User Guides, and Maintenance Guides for any of these programs are available by sending one double-sided, double-density diskette for every three programs requested (*see*address below). Documentation related to the field note system is also available upon written request. For computers other than IBM XT or AT some modifications may be necessary.

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ENGINEERING AND TERRAIN GEOLOGY PROGRAMS

033. Summary of Activities 1986, Engineering and Terrain Geology Section

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The field activities of the Section were again widely distributed throughout the Province, from Rainy River in the west to Kirkland Lake in the east, and from Pickle Lake in the north to many localities in the south from Windsor to Cornwall. With approximately one-third of the field parties being funded from base budget, the majority of projects were funded from external sources. New projects started this year were, in most cases, funded through the Canada-Ontario Mineral Development Agreement (COMDA).

A.J. Bajc and F.J. Kristjansson commenced the mapping of the Quaternary geology, at a scale of 1:50 000, in the Fort Frances-Rainy River and Beardmore-Geraldton areas respectively. In both areas, one of the major objectives is to provide reliable details of the Quaternary geology, stratigraphy, and history. This information is to be used as a base for drift exploration programs, which are growing in number and in importance as exploration tools in the search for possible new mineral deposits which lack surface outcrop. Both mapping programs will be supplemented by drilling to elaborate the stratigraphic detail and to provide samples for laboratory testing.

In the western portion of the Fort Frances-Rainy River area, Bajc reports the presence of two major till sheets: a) an older, lower, noncalcareous till with predominantly local lithologies; and b) a younger, upper, calcareous till with pebbles transported for distances of approximately 500 km or more from the northwest. Lake Agassiz II fine sand, silt, and clay, up to depths of 3 m, cover the calcareous till. The lower till, with the local pebble lithologies, is the obvious exploration target but will involve deep overburden drilling techniques in the southern part of the map area. Ice-contact sand and gravel deposits, associated with the older noncalcareous till sheet and which underlie the upper, calcareous till sheet in the south, may indicate the presence of economically significantly aggregate deposits.

Kristjansson, in the Beardmore-Geraldton area, reports four types of till, and evidence for ice flow to the south and later to the southwest. A gritty, silty sand till, with pebbles of local provenance, occurs as a thin veneer on bedrock but is not commonly widespread. Nevertheless, this till appears to be the appropriate target for drift exploration programs. A calcareous till, with numerous clasts from rocks occurring in the James Bay Lowland, and occurring in both a compact silty variety and a loose sandy form, is the most widespread till in the area but should be avoided in drift exploration programs. A local clast-rich sand till, which occurs commonly in the southwest of the study area, may have potential as a drift sampling medium. Kristjansson notes the similarity of the stratigraphy in the Beardmore-Geraldton area with that in the Hemlo area and suggests that the framework for exploration geochemistry developed in the Hemlo area could probably be applied in the Beardmore-Geraldton area. The Beardmore-Geraldton area appears to have a variety of ice-contact and glaciofluvial outwash deposits which probably provide more than an adequate supply of sand and gravel for local purposes.

In the Shining Tree area, P.F. Finamore commenced the mapping of the Quaternary deposits of the area at a scale of 1:50 000, also with a major objective of providing a reliable account of the surficial deposits to assist in drift exploration programs.

Finamore reports only one till, a stony, silty sand till, in the area, although both lodgement and melt-out facies are widely seen. The till cover varies in thickness from less than 1 m to over 50 m, with the thicker deposits mostly in the southern part of the map area. Directional indicators of ice movement cover a wide range, but the most dominant direction of 185° azimuth appears also to represent the most recent movement.

Glaciolacustrine deposits cover most of the map area, but esker, glaciofluvial outwash, and deltaic deposits are commonly encountered and would probably meet much of the local need for aggregate resources.

In an extension of the regional mapping activities in the Hemlo area reported in 1985, R.S. Geddes demonstrates at the Page Williams A Zone the character of glacial dispersion in the area. Geddes previously reported the occurrence of four tills in the Hemlo area, one of which has a carbonate-rich matrix and, where stony, a high percentage of clasts of non-local or exotic rock types. The till immediately below this exotic till is one that reflects a mixture of the earliest pre-existing till and this "exotic" till. The uppermost sandy till contains numerous clasts of local origin.

Till samples taken immediately above the ore zone, and along profiles across the ore zone, reveal an anomalous dispersion of the gold values in the till. Geddes suggests this may be explained by the effect thereon of the bedrock topography and a change in glaciodynamics. These factors must then be considered in any drift exploration program in the Hemlo area.

Other Quaternary studies were undertaken in the Matheson area under the BRIM program, and in the Opapamiskan area north of Pickle Lake. The individual Quaternary reports in each program are grouped with the other articles on each project area elsewhere in this volume.

In southern Ontario, field studies were commenced in the Parry Sound and Barrie-Elmvale areas, and were continued in the Brampton area.

P. Kor commenced mapping in the Parry Sound area in the southern part of the assigned area which extends north to the French River. Glacial deposits in the area are generally thin and variably dispersed. The whole area was inundated by the waters of glacial Lake Algonquin after the ice had disappeared.

Two till facies have been identified; one a dense silty sand till with minor clasts, and the other a loose sand and silt till with numerous clasts. Till deposits are not thick, and exposed bedrock abounds, but many boulder lag deposits suggest a much wider distribution of till which has been removed in large part by erosion particularly during submergence by glacial lake waters.

Ice-contact and glaciofluvial deposits are not abundant in the area, and glaciolacustrine deposits are only found in broad, shallow bedrock depressions. Organic remains, possibly of glacial Lake Nipissing origin, were found in silt and sand near Killbear Provincial Park.

Economic deposits of sand and gravel are lacking. Known aggregate resources are generally too fine grained, or contain an abundance of over sized material, and all deposits are too small in size to represent good, long term, local resources.

P.J. Barnett commenced mapping in the Barrie-Elmvale area, at a scale of 1:50 000, and with more emphasis on stratigraphy than when the area was first mapped more than 40 years ago at a much smaller scale. The current mapping should also provide more information on several, suspected, buried aggregate deposits.

Barnett reports three subglacial till units, each with an associated sequence of glaciolacustrine sediments. The two older till units are both truncated by large U-shaped valleys crossing the map area, which indicate that the valleys were formed before or during the last advance of the ice. Many erosion features noted on the bedrock surface in the area will, without doubt, assist in unraveling the glacial history of the area.

In the Brampton area, P.F. Karrow continued mapping the western half of the map area, which is underlain by red mudstone of the Queenston Formation. Quaternary mapping continues in the eastern portion of the map area, which is essentially underlain by grey shales of the Georgian Bay Formation. The eastern half of the map area has a much higher degree of urbanization and much of the original surface form and materials have been disturbed. Original surface materials of silts and clays are widespread, and are underlain by Halton Till which is grey in colour in the east but, where the ice has incorporated shales of the Queenston Formation, the resulting till is brown—even reddish brown in places.

Early in 1986, six boreholes were drilled to supplement the data available in 4000 boreholes collected in the Brampton area for the Urban Geotechnical Data Bank. The data bank information, and that obtained in the drilling program, not only supplemented the surface information collected by Karrow, but also provided additional useful information for the determination of the bedrock topography and the drift thickness. D.C. Roumbanis and O.L. White provide a brief summary of the drilling results showing that three holes were taken to depths of over 30 m and two holes were taken to 10 m or less. The holes that penetrated bedrock assisted in delineating a bedrock depression, a bedrock outlier, and a buried valley of the ancestral Credit River.

Field activities of the Paleozoic/Mesozoic Subsection concentrated on: a) the preparation of the geological component of a report on the Limestone Industries of Ontario, being prepared for the Ontario Ministry of Natural Resources; and b) a study in the Bruce Peninsula of the Eramosa Member of the Amabel Formation as part of the COMDA-funded Mid-Ontario Building Stone Project.

V. Mazur and colleagues have visited all active and licensed quarries in southern Ontario to put together the geological base for the study. This involved visits to 200 operations. Visits were also made to some of the 400 inactive quarries throughout the Province.

The materials quarried range in age from Lower Ordovician to Upper Devonian. The geographical distribution of the quarries depends upon bedrock type, overburden thickness, and local demand. Geological descriptions have been prepared for individual quarries and these, together with reports on regional characteristics, will form part of the final report.

The initiation of this project was responsible for the establishment of a computer accessible inventory of active and abandoned quarries which should prove useful in future handling of the data generated.

The Mid-Ontario Building Stone Project is reported here by D. Armstrong, who not only investigated active and abandoned quarries in the Eramosa Member to ascertain the extent of immediately accessible resources but also mapped the Eramosa Member at a reconnaissance level to investigate the regional extent of the unit.

The Eramosa Member of the Amabel Formation is a thin-bedded, grey to dark brown, fine crystalline, bituminous dolostone, and is extensively quarried for a variety of applications. The Eramosa overlies the Wiarton/Colpoys Bay Member of the Amabel Formation which is also widely quarried as a building stone and is currently being quarried to provide facing stone for the new Canadian Embassy building in Washington, D.C.

Armstrong reports that within the Eramosa Member three lithotypes can be identified—one more than previously reported. The member itself can be subdivided into four units based on the stratigraphic distribution of the three lithotypes. All four units can be identified in the quarries on Oliphant Road, Wiarton. The lithotypes and the units are related to the various product types in Armstrong's report. Reconnaissance mapping shows that the Eramosa Member extends well beyond the various quarry limits.

The staff of the Aggregate Assessment Office continued their assessment of the aggregate resources in the designated townships of southern Ontario and commenced a COMDA-funded aggregate assessment in Haliburton County.

R. Gorman and S. Szoke report on the continued field work in the townships in Grey and Northumberland Counties. The work in Euphrasia Township completes the field work for Grey County and indicates that Euphrasia Township is not as well endowed with aggregate resources as those townships farther south in Grey County. Nevertheless, small deposits of good quality ice-contact kamelike features and eskers do occur. The larger deposits that have been worked do have an excessive percentage of fines which must be removed during processing. Where appropriate, bedrock resources could be available for a variety of products.

Four townships in Northumberland County investigated in 1986 include shoreline deposits of glacial Lake Iroquois, as well as the ice-contact deposits associated with the Oak Ridges Moraine. The Oak Ridges Moraine has been a source of good quality aggregate over the years and much is probably still available. Overlying sand and till units tend to discourage exploration, and many parts of the moraine are not exploited. The bedrock units (Verulam and Lindsay Formations) which underlie the four townships are not generally suitable for use in the production of crushed stone although the Lindsay Formation is quarried elsewhere for use in portland cement manufacture.

The aggregate resources of thirteen townships in Haliburton County were investigated in 1986 by G. Jones, M. Gauvreau, and S. Szoke. Most use (for construction) is made of the glaciofluvial outwash deposits in valleys, although some esker deposits, which are not yet exploited, may prove to be quite useful. The aggregate in the area is generally satisfactory from a quality point of view, although the abundant mica flakes in the sands may reduce the strength of the bond in concrete mixes.

Bedrock in the area forms part of the Grenville Province of the Canadian Shield. In many places the bedrock is hard and resistant to weathering, and has been quarried in several localities for a variety of products. On the other hand, some of the bedrock has weathered to a considerable degree and is unsuitable for aggregate production.

034. Quaternary Geology of the Beardmore-Geraldton Area, District of Thunder Bay

F.J. Kristjansson[1]

[1]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Previous field research, conducted primarily at a reconnaissance level, concerned the surficial geology (Zoltai 1965, 1967) and engineering geology (Gartner 1980a, 1980b) of the study area. Additional field investigation, concerning the glacial and Quaternary geology of the Beardmore-Geraldton area, includes studies undertaken by Sado (1975) and Kristjansson *in* Patterson *et al.* (1984, p.97, 98; 1985, p.127). During the 1986 field season a program of detailed Quaternary geological mapping at a scale of 1:50 000 was initiated in the Beardmore-Geraldton Metavolcanic-Metasedimentary Belt. In the 1986 season, field mapping commenced at the eastern end of the target area and has resulted in the completion of the mapping of the Geraldton (42 E/10) and Wildgoose Lake (42 E/11) map sheets.

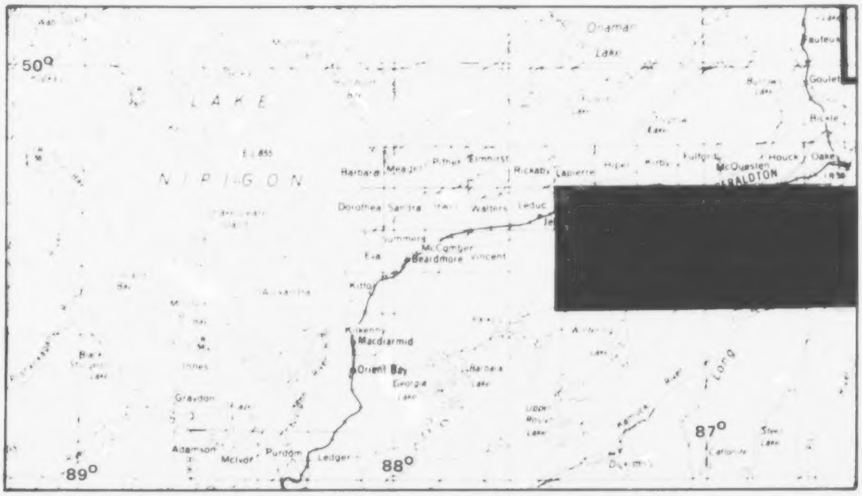
Satellite imagery enlargements (1:250 000) and conventional aerial photography (1 inch to 1 mile and 1 inch to 1/4 mile) were used during the survey. The satellite imagery provided a regional overview of the study area. The contrast between bedrock-dominated and drift-dominated terrain was particularly evident. Conventional aerial photography was used to prepare the detailed mapping, and a preliminary interpretation of this imagery was subjected to a program of field verification.

An objective of the field program was to obtain as many points of ground truth as possible in the study area. All trafficable roads were traversed by vehicle, and test pitting was conducted along these roads at intervals which varied from 50 m to 400 m. All sand, gravel, and borrow pits were examined. The resultant database was further supplemented by conducting canoe traverses along lakeshores and foot traverses to isolated locations away from the road network.

BEDROCK GEOLOGY

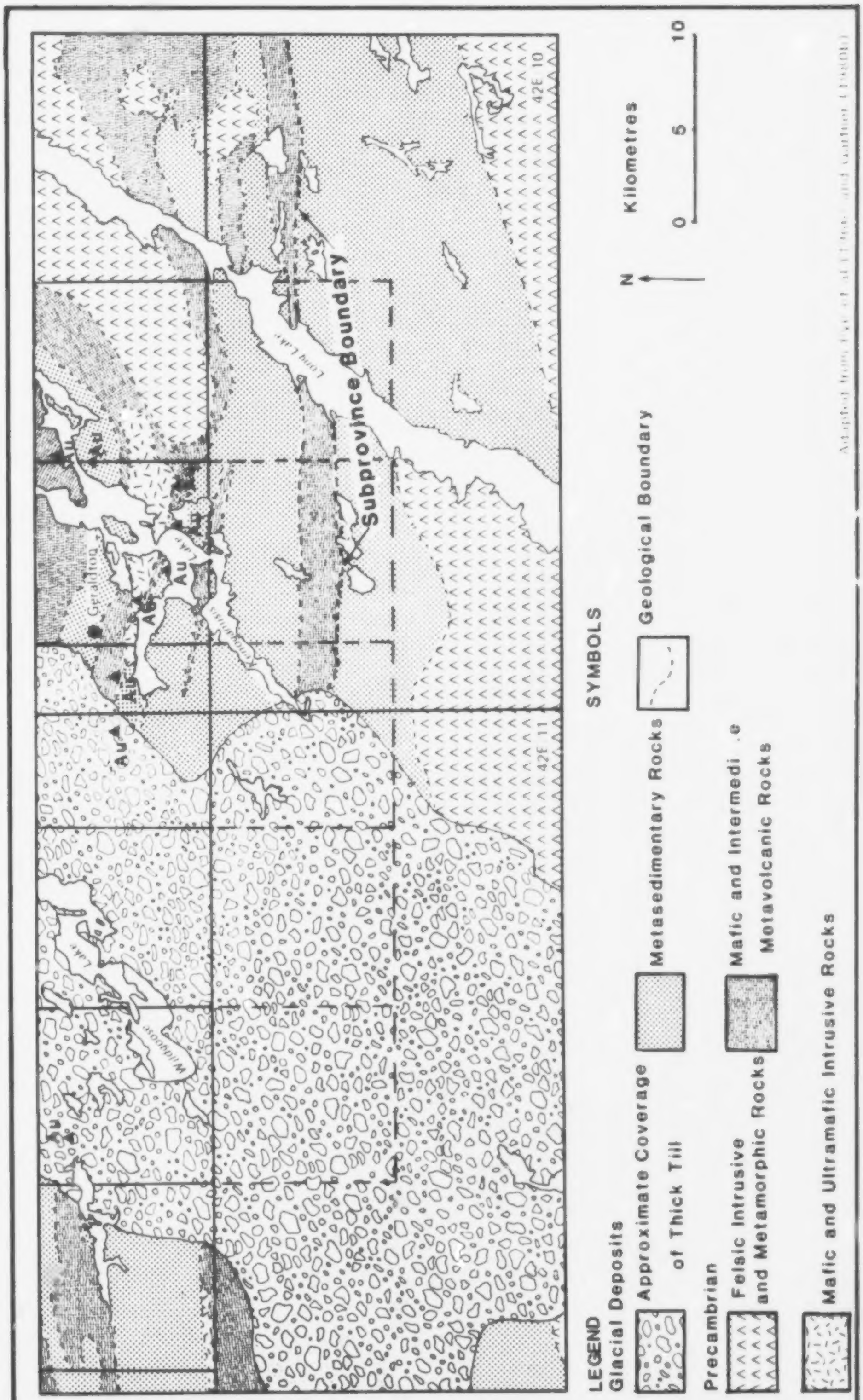
The northern part of the study area is underlain by bedrock of the Beardmore-Geraldton Belt, which comprises part of the Wabigoon Subprovince, and the southern portion is underlain by a part of the Quetico Subprovince (Figure 034.1). The Beardmore-Geraldton Belt is a predominantly metasedimentary sequence intercalated with mafic to intermediate metavolcanic rocks. A number of small-scale, lenticular, mafic and felsic plutonic bodies are associated with this greenstone belt. The Quetico Subprovince in the study area is represented by a thick and extensive metasedimentary-migmatitic sequence, which is flanked to the south by an area of felsic intrusive and metamorphic rock. Both Beardmore-Geraldton Belt and Quetico Subprovince rocks were intruded by a system of north-trending diabase dikes (Mason and White, in press).

The Beardmore-Geraldton Metavolcanic-Metasedimentary Belt, which is currently the subject of substantially increased mineral exploration efforts, has a high potential for gold and base metals (Mason and White, in press).



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles


LEGEND
Glacial Deposits
Approximate Coverage of Thick Till
Metasedimentary Rocks
Precambrian
Felsic Intrusive and Metamorphic Rocks
Mafic and Intermediate Metavolcanic Rocks
Mafic and Ultramafic Intrusive Rocks
SYMBOLS
Geological Boundary
N
Kilometres
0
5
10
Subprovince Boundary
Geraldton
Long Lake
Windigoostigwan
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42E 11
42E 10
Adapted from Fyon et al (1988) and author (1988)

Figure 034.1. Relationship between thick till cover and Beardmore-Geraldton Metavolcanic-Metasedimentary Belt.

QUATERNARY GEOLOGY

Glacial striae, along with such features as roche moutonnée, crag and tail, and fluted moraine, indicate an early glacial advance to the south and a late glacial advance to the southwest. Evidence of the early advance is rare. Glacial striae, which trend about 190° azimuth, remain in locations which represented protected lee side environments during the late glacial advance. Glacial striae of the late advance, as determined by crosscutting relationships, indicate a marked divergence of glacier flow to the west. Glacial striae observed in the eastern part of the study area (i.e. east of Long Lake) trend about 200° to 210° azimuth. Ice-flow indicators examined in the central part of the study area (i.e. Kenogamisis Lake to Wildgoose Lake) trend about 220° to 235° azimuth. Ice-flow measurements in the western part of the study area (i.e. in the vicinity of Jellicoe) indicate glacier flow trends of about 240° to 250° azimuth. This suggests that a regional bedrock high, which is situated south of the study area along the north shore of Lake Superior, diverted ice flow toward the Nipigon basin. The possibility that topography exerted a strong influence on the late glacier flow implies a relatively thin, late Wisconsinan ice mass.

Terrain characterized by negligible drift (i.e. Bedrock-Dominated Terrain) or thin, discontinuous drift (i.e. Bedrock-Drift Complex) is well represented in the vicinity of Long lake and areas east thereof, Geraldton, immediately south of Wildgoose Lake, and south of Partridge Lake.

The most notable characteristic of the study area is the presence of extensive deposits of till. On the basis of texture, structure, lithology, and geotechnical criteria, four varieties of till were defined.

A gritty, silty, sand till, which appears to be relatively rare in the study area, occurs generally as a thin veneer overlying bedrock. The lithology of this till appears to be dominated by rock types of local provenance. This particular till variety probably represents an excellent sampling medium for till geochemistry programs.

A fine-grained, calcareous till, which can be subdivided into a lower, compact, fissile, gritty, silt till and an upper, loose, gritty, sandy, silt till, appears to form the dominant till of the study area. This till in general occurs as a thick and extensive sheet. The lithology of this till is dominated by an obvious exotic component (e.g. abundant subrounded pebbles and cobbles of limestone and dolostone derived from Paleozoic terrain of the James Bay Lowland).

A clast-rich, gritty, sand till, which occurs as a thin, discontinuous veneer overlying either bedrock or fine-grained, calcareous till, comprises a common surficial deposit in the southwestern part of the study area. Local rock types appear to comprise a substantial component of the lithology of this till.

Glaciofluvial ice-contact and glaciofluvial outwash sediments are well represented in the study area. Three major esker-kame complexes, which trend south-southwest to southwest across the study area, comprise prominent landform-sediment systems in the extreme southeastern part of the study area, in and to the southwest of McKelvie and Salsberg Townships, and in and to the southwest of McQuesten, Fulford, Lindsley, and Vivian Townships. Glaciofluvial outwash sediments occur in abundance in the extreme southeastern and western parts of the study area. The latter deposits document in part a major meltwater system which, according to Zoltai (1965), flowed north along the present-day course of the Namewaminikan River and then west toward the Nipigon basin.

Ice-marginal deltas, which indicate the development of a proglacial lake in the Geraldton area, are a characteristic feature of the terrain adjacent to Kenogamisis Lake. The elevation of the topset bedding of these deltaic bodies indicates that the water level at the time of delta construction was approximately 20 m higher than that of contemporary Lake Kenogamisis. The fact that this water plane can be extended across the height of land separating Kenogamisis Lake from Long Lake suggests that these basins may have been confluent. Whether this glacial lake represents an early stage of Glacial Lake Nakina, or should merely be considered an earlier, probably ephemeral, ice-contact lake, will be the subject of further study. Rhythmically laminated clayey silt and silty clay, which were observed with some frequency in the vicinity of the Kenogamisis Lake and Long Lake basins, is representative of the lower energy, deeper water, depositional environments of this glacial lake.

Alluvial sediments, present in contemporary floodplain environments, or preserved in the form of early Holocene terraces, form only a minor part of the Quaternary geology of the study area.

Organic deposits occur generally as thin (1 to 2 m), continuous veneers overlying relatively impermeable substrates such as till or fine-grained, glaciolacustrine sediment. Relatively extensive deposits of organics may be observed in the north-central and southwestern parts of the study area.

APPLIED QUATERNARY GEOLOGY

Till represents a prime sampling medium for mineral exploration in areas of glaciated terrain dominated by a thick and extensive drift sheet. An important objective of the field program as a consequence was to investigate in detail the sedimentology and stratigraphy of the varieties of till present in the study area. One hundred and twenty-three till samples were collected. In order to characterize these sediments, and to assess their utility from a mineral exploration perspective, a variety of laboratory analyses will be conducted. Although the results of these analyses are still forthcoming, a number of field observations of immediate significance to programs of mineral exploration are apparent.

A thick, generally continuous sheet of till was documented in the vicinity of, and to the south and southwest of, Turkey Lake and Wildgoose Lake. The till sheet in part overlies a portion of the very highly prospective Beardmore-Geraldton Metavolcanic-Metasedimentary Belt (Figure 034.1). The thickness of the till sheet, which can be as thick as 45 m (Kristjansson *in* Patterson *et al.* 1984, p.97, 98), represents a distinct impediment to conventional programs of mineral exploration. In addition, the presence of abundant, nonlocal, calcareous till must be considered a constraining factor with respect to till geochemistry programs. Till sampling techniques which provide for both deep sampling and accurate till identification must be considered. The similarities between the till varieties described in the Geraldton area and the till sequence defined in the Hemlo area are remarkable. This suggests that the framework for exploration geochemistry developed in the Hemlo area (Geddes and Kristjansson 1986) is directly applicable to the Geraldton area.

The planning and development of municipal works and mining operations requires knowledge of, and access to, the aggregate resources of the area. The potential for substantial deposits of gravel to occur in those parts of the study area influenced by glaciofluvial ice-contact and outwash sedimentation is high.

RELATED RESEARCH

H. Thorleifson, Geologist, Terrain Sciences Division, Geological Survey of Canada, has undertaken the Federal Government component of the Beardmore-Geraldton Quaternary Geology (COMDA) Project. During the 1986 field season Thorleifson completed a till transect which extended from the James Bay Lowland, through the Geraldton area, to the Terrace Bay area. S.R. Hicock, Assistant, Professor, Department of Geology, University of Western Ontario, completed the field component of a study of the carbonate till depositional processes in the Geraldton area. An Ontario Geoscience Research Grant provided the funding for this research. S.P. Gaudino, Graduate Student, Department of Geology, Lakehead University, has begun an M.Sc. thesis on the sedimentology and stratigraphy of a number of deltaic deposits located in the study area. Gaudino intends to emphasize lateral relationships within deltaic depositional systems through an analysis of sand body architecture (Miall 1985).

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035. Quaternary Geology of the Fort Frances–Rainy River Area (Western Half)

A.F. Bajc

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Quaternary mapping of the western half of the Fort Frances-Rainy River area began during the summer of 1986. The Ontario-Minnesota International Border delimits the southern margin of the study area and the 49th Parallel of Latitude delimits the northern boundary. The Lake of the Woods and the 94th Parallel of Longitude confine the map area on the west and east respectively. The map area includes the Rainy River (52 D/15 and 52 D/10), the Pinewood (52 D/9), and the Arbor Vitae (52 D/16) National Topographic System (NTS) map sheets. The project is designed to establish a framework of Quaternary geology which would apply to mineral exploration and aggregate evaluation. Mapping will be extended east to Rainy Lake, and overburden drilling is planned as follow-up.

Highway 11 traverses the study area and forms the main east-west corridor. Access throughout much of the area is provided by numerous township, concession, and forestry access roads.

Several investigations related to Quaternary geology have been undertaken within the study area. Earlier studies include a surficial geology and soil study within the Rainy River District by Johnston (1915) and a reconnaissance soil survey by Hills and Morwick (1944).

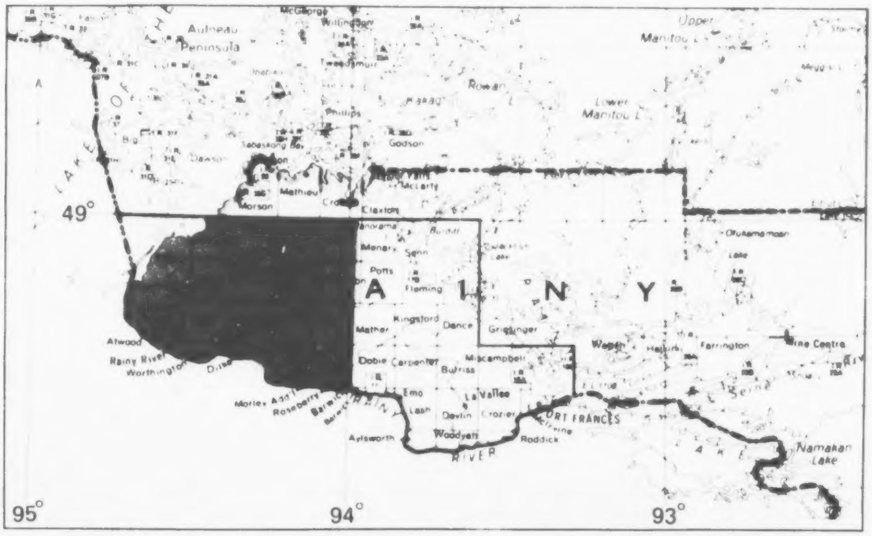
More recently, Zoltai (1961, 1965) has described the glacial deposits of northwestern Ontario on a reconnaissance level. Other recent work in the study area includes an Engineering Geology Terrain Study by Hallett and Roed (1980) and a peatland inventory of the Rainy River District (Northland Associates Limited 1984).

BEDROCK GEOLOGY

Limited outcrop within large parts of the map area has resulted in a simplified conception of the bedrock geology. The geology of the southern half of the study area has largely been inferred from widely scattered outcrops and geophysical interpretations. More abundant outcrop in the northern half of the study area has allowed a better understanding of the bedrock geology. The southern half has been interpreted as predominantly massive to pillowed mafic volcanic rocks of Early Precambrian age, whereas the northern half is mainly felsic to intermediate plutonic rocks of Middle to Late Precambrian age. Of interest is the westerly extension of the Quetico Fault through the southern part of the map area. Mapping of the northeastern corner of the Arbor Vitae NTS sheet was undertaken by Blackburn (1976). The bedrock geology of the remainder of the study area has been documented in a compilation map by Blackburn (1979).

QUATERNARY GEOLOGY

Two major ice-flow directions have been documented in the study area. An early, strong, south-southwesterly direction is crosscut by a later, weaker, east-northeasterly trending ice flow.


Aulneau Peninsula
McGeorge
Willingdon
Tweedsmuir
Upper Manitou L
Rowan
Lower Manitou L
Phillips
Godson
Sabaskong Bay
Dawson
Big
LAKE OF THE WOODS
Mathieu
McCarty
Morson
Claxton
49°
Menary
Senn
Potts
Fleming
R A I N Y
Kingsford
Dance
Mather
Griesinger
Atwood
Rainy River
Worthington
Dilke
Dobie
Carpenter
Miscampbell
Burriss
Wegg
Halkirk
Farrington
Mine Centre
Emo
La Vallee
Morley
Roseberry
Barwick
Lash
Devlin
Crozier
FORT FRANCES
Aylsworth
Woodyatt
Roddick
RAINY RIVER
Namakan Lake
95°
94°
93°

LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

Thicknesses of glacial and non-glacial deposits are highly variable in the study area. Two terrain types can be defined. The northern part of the map area is characterized by localized pockets of thick drift set amongst the abundant bedrock outcrop whereas, in contrast, the southern part contains very little outcrop. Water well records suggest overburden thicknesses of greater than 60 m occur in places in the south.

The oldest drift sheet recognized is attributed to the Patrician lobe of the Laurentide ice sheet. Thin deposits of non-calcareous, dense, silty sand till commonly occur on the stoss sides of rock knobs in the northern part of the map area. Loose, sub-stratified, flow and melt-out tills are encountered on the lee sides of rock knobs. Pebble counts from this till sheet contain predominantly local lithologies in the dense facies and semi-local lithologies in the loose facies. Similar deposits may extend southward beneath thick deposits of younger sediments. Only non-calcareous, ice-contact deposits of stratified sand and gravel have been encountered to the south beneath younger calcareous sediments.

A halt in the retreat of the Patrician ice front at the northeastern corner of the Arbor Vitae map sheet resulted in the deposition of ice-contact sands and gravels and the formation of the northwest-trending Lake of the Woods-Rainy Lake Moraine (Zoltai 1961).

Either synchronously with, or shortly following, the melting of the Patrician ice, a suite of highly calcareous sediments were deposited either directly or indirectly by Keewatin ice flowing from the west. Lake Agassiz I fronted this ice mass. Compact deposits of gritty and pebbly till varying in texture from predominantly sandy silt in the west to clayey silt and silty clay in the east are encountered.

Clayey glaciolacustrine sediments deposited proglacially were incorporated into the till and may be preserved in a distorted state. A debris-rich, floating ice shelf associated with the retreating ice front resulted in the deposition of gritty glaciolacustrine rhythmites and subaqueous flow tills.

Pebble counts from the carbonate-rich till suggest a distal origin. The till sheet contains up to 80 percent Ordovician and Silurian dolostone and Devonian limestone and smaller amounts of Cretaceous shale and Tertiary lignite. A transport distance of up to 500 km is suggested for some of these lithologies, with the lignite providing a particular useful marker.

This package of calcareous tills and glaciolacustrine sediments is capped by lacustrine deposits of Lake Agassiz II. These deposits range from very fine sand to thinly laminated silt and clay and reach maximum observed thicknesses of 2 to 3 m. Organic remains (plant detritus and molluscs) are commonly found within these sediments.

Beach and nearshore deposits associated with Lake Agassiz II are found throughout the map area below the 350 m contour line. These sands and gravels rarely exceed 3 m in thickness and are usually strongly calcareous. They are usually underlain by either deep water, glaciolacustrine and lacustrine clay or calcareous till. Erosional features also delimit shoreline morphologies.

Extensive peatlands averaging 2 to 3 m in thickness occupy the lowlands in the western part of the map area as well as in isolated lowlands in the eastern part. An evaluation of this resource has been carried out by the Ontario Geological Survey in the Rainy River area (Northland Associates Limited 1984). A small Sphagnum peat moss plant is in operation near the Town of Barwick. The Sphagnum is being extracted from a peatland approximately 10 km north of Pinewood.

APPLIED QUATERNARY GEOLOGY

The field work to date has revealed two characteristics of the glacial drift that are directly applicable in the search for mineral resources. Thick deposits of Quaternary sediments conceal much of the underlying bedrock and impose constraints on mineral exploration. The lower, locally derived, non-calcareous till sheet is the desirable sampling medium as opposed to the calcareous till sheet which is found on the surface throughout much of the map area. One is thus limited to deep overburden drilling techniques as an exploration tool over much of the southern part of the map area.

Buried deposits of non-calcareous glaciofluvial sediments have been encountered beneath deposits of calcareous till and glaciolacustrine silts and clays primarily in the southern and eastern part of the map area. These deposits have a general east-west trend and may be related to ice-marginal positions of the Patrician ice mass. There is potential for further discoveries of buried aggregates in the vicinity. Deposits of beach and nearshore sands and gravels are considerably more limited and should therefore not be relied upon as a primary aggregate source.

The peat resources of the area have been outlined by the Ontario Geological Survey (Northland Associates Limited 1984). They should be considered a valuable commodity for horticulture, the peat by-product industry, and fuel.

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036. Shallow Drilling Program, Brampton Area, Southern Ontario

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INTRODUCTION

In 1984, mapping of the surficial deposits in the Brampton area (NTS 30 M/12) was commenced by P.F. Karrow (Professor, Department of Earth Sciences, University of Waterloo, Waterloo). The physiography and glacial geology of the area have been summarized by Karrow (1984, 1985). The eastern portion of the map area contains the western part of Metropolitan Toronto, and includes the Cities of Mississauga, Etobicoke, and Brampton. These highly developed, urbanized areas provide few good exposures to aid the geologist in mapping of the surficial deposits. Thus, subsurface data consisting of engineering boreholes and waterwell records has been compiled from various sources. This data permits the identification of the surficial deposits in the urbanized areas, as well as providing the depth to the surficial deposit-bedrock contact over the map area.

More than 4000 separate boreholes have been collected in the Brampton area from several municipalities, public agencies, and engineering consultants. The borehole data has been used in conjunction with waterwell data to construct bedrock topography and drift (overburden) thickness maps for the area. This data has been supplemented by information obtained in a shallow drilling program reported herein. The maps, making use of all available data, will subsequently be released as part of the Ontario Geological Survey Bedrock Topography and Drift Thickness Series of Preliminary Maps.

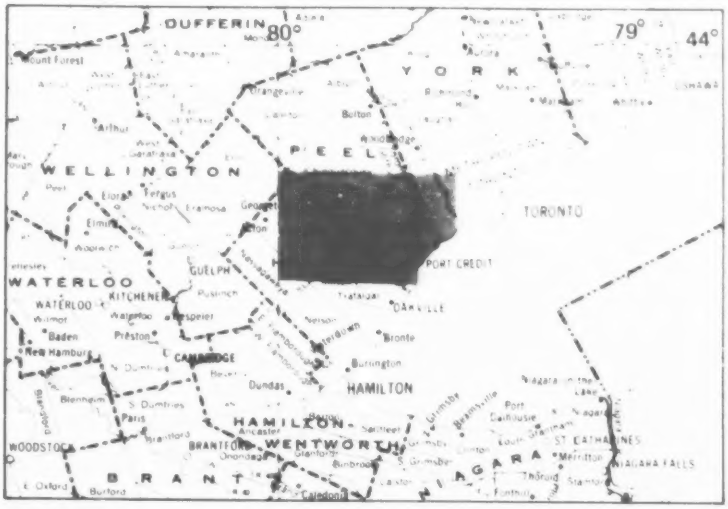
BEDROCK TOPOGRAPHY

The bedrock topography, east of the Niagara Escarpment, is characterized as a broad sloping plain incised by valleys to depths of over 15 m. The present Credit and Humber River valleys lie largely within these bedrock valleys which are now drift filled. The subsurface data indicates the presence of several other buried bedrock valleys, one such feature being located approximately 2 km south of Huttonville, and trending parallel to the present Credit River valley.

Several buried bedrock knobs and outliers occur on the broad bedrock plain, and appear to have influenced the present drainage patterns. The most notable buried outlier is found in Esquesing Township (to the west of Ashgrove), centred roughly in lot 12, concessions V and VI. It is similar to the Victoria outlier (White 1975, p.13-14) which lies approximately 20 km to the north in the Bolton map area. Low relief bedrock knobs occur near Eglinton Avenue and McLaughlin Road in Mississauga, near Mississauga Road just south of Huttonville, and in Chinguacousy Township (Caledon) in the vicinity of lot 22, concession V.

DRILL SITE SELECTION

Once the available data had been compiled and reviewed, several areas were noted where the subsurface information was either lacking or suspect. It was thus necessary to verify the preliminary bedrock topography interpretation and the subsurface stratigraphy by drilling a series of boreholes in these areas. In consultation with P.F. Karrow, six specific drill sites were chosen.


DUFFERIN
80°
79°
44°
YORK
Mount Forest
Orangeville
Bolton
Arthur
PEEL
WELLINGTON
Elora
Fergus
Eramosa
TORONTO
GUELPH
PORT CREDIT
WATERLOO
KITCHENER
WATERLOO
Wilmot
Baden
Preston
New Hamburg
Puslinch
Trafalgar
OAKVILLE
Nelson
Bronte
CAMBRIDGE
Burlington
Dundas
HAMILTON
Blenheim
S. Dumfries
Paris
HAMILTON-WENTWORTH
Ancaster
WOODSTOCK
BRANTFORD
Onondaga
Glanford
Saltfleet
Grimsby
Niagara-on-the-Lake
Port Dalhousie
ST. CATHARINES
NIAGARA
Merritton
NIAGARA FALLS
Thorold
BRANT
E. Oxford
Burford
Caledonia

LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

Permission was obtained from the appropriate agencies, and the six drill sites were located on either public road allowances or public land. Each site was field checked to ensure ready accessibility, and that all utilities and services (underground and overhead) were properly identified prior to drilling.

DRILLING FIELD OPERATIONS

Drilling was conducted over a two-week period in March 1986, using a BOA-H.T. truck-mounted drill rig with a two-man crew, supplied by Dominion Soil Investigation Incorporated. In total, over 525 feet (160 m) were drilled. Continuous samples were obtained using a 5 foot (1500 mm) split-tube sampler inside standard hollow stem augers. The sampler was advanced with the augers in two 2.5 foot (750 mm) strokes, producing an undisturbed sample of approximately 3 inches (80 mm) in diameter. Samples were logged in detail on-site, and then sealed in split PVC tubes or plastic sample bags for transport to the laboratory for further analysis. The samples are currently stored in the Toronto area.

Sample recovery was exceptionally good in cohesive soils of firm to stiff consistency, such as clays and clay/silt tills. In very hard tills the sampler could only be advanced about 2 feet (600 mm) before skin friction on the inner wall of the sampler would be too great to permit further progress without sample disturbance. In noncohesive silts and sands, a "catcher" was used to enhance sample recovery.

DRILLING RESULTS

As previously stated, the primary objective of the drilling program was to verify the preliminary bedrock topography interpretation, as well as to provide stratigraphic detail at the chosen sites. The depth to bedrock for each hole is reported herein, and the details of the drift stratigraphy will be reported elsewhere. In addition the UTM co-ordinates, the surface and bedrock elevations are listed below for each borehole location.

BOREHOLE SUMMARY—BRAMPTON AREA SHALLOW DRILLING PROGRAM

Borehole 1 (UTM 4819520N/587840E)

Surface Elevation 685 feet (208 m), Bedrock Elevation 585 feet (178 m)

0-100 feet (0-30 m): Overburden

100 feet (30 m): Refusal (assumed red shale bedrock (Queenston Formation))

Borehole 2 (UTM 4826930N/587100E)

Surface Elevation 865 feet (264 m), Bedrock Elevation 841 feet (256 m)

0-24 feet (0-8 m): Overburden

24 feet (8 m): Bedrock - red shale (Queenston Formation)

Borehole 3 (UTM 4827905N/486110E)

Surface Elevation 865 feet (264 m), Bedrock Elevation 718 feet (219 m)

0-147 feet (0-45 m): Overburden

147 feet (45 m): Bedrock - red shale (Queenston Formation)

Borehole 4 (UTM 4839740N/589900E)

Surface Elevation 875 feet (267 m), Bedrock Elevation 844 feet (257 m)

0-31 feet (0-10 m): Overburden

31 feet (10 m): Bedrock - red shale (Queenston Formation)

Borehole 5 (UTM 4832620N/592700E)

Surface Elevation 725 feet (221 m), Bedrock Elevation 589 feet (180 m)

0-136 feet (0-41 m): Overburden

136 feet (41 m): Bedrock - red shale (Queenston Formation)

Borehole 6 (UTM 4830840N/602340E)

Surface Elevation 545 feet (166 m), Bedrock Elevation <475 feet (<145 m)

0-70 feet (0-21 m): Overburden

Hole terminated at 70 feet (21 m)

The bedrock depths encountered in the drilling program, for the most part confirmed the preliminary bedrock topography interpretation. Borehole 1 helped define the eastward extent of a large closed bedrock depression near Milton. Boreholes 2 and 3 further delineated the buried outlier just to the west of Ashgrove, whereas Borehole 4 confirmed the low relief bedrock knob in Chinguacousy Township (Caledon). Borehole 6 was intended to verify a deep depression near the Village of Meadowvale, but the drilling had to be terminated before bedrock was encountered.

The most unexpected results were from Borehole 5 where the bedrock was encountered over 50 feet (15 m) deeper than had been anticipated. This clearly indicates that the bedrock valley is wider than the existing Credit River valley at this point, and suggests that the aforementioned buried valley south of Hultonville may, in fact, connect with the Credit River valley just east of Norval. The true extent of this buried valley could be better defined by undertaking a detailed geophysical survey in this vicinity.

ACKNOWLEDGMENTS

Field work described herein was under supervision by the senior author. The Ontario Geological Survey wishes to thank the public agencies who provided access to their properties, as well as to the private landowners who permitted temporary use of their adjacent properties as necessary.

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037. Till Genesis and Glacial Dispersion, Page Williams A Zone, Hemlo

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INTRODUCTION

This report provides a preliminary evaluation of till genesis and its effects on glacial dispersion over the Page Williams A Zone at Hemlo. Detailed till sampling over the area was part of a geochemical study undertaken to investigate metal dispersion in a variety of surface materials (humus, soil, and till) within the confines of the A zone (Fortescue and Geddes 1983). The humus results have been reported by Fortescue (1985). The till study has been augmented by continued mapping and investigation of the Quaternary geology of the area (Geddes *et al.* 1985).

The Page Williams A Zone is located in the centre of the recent gold mine developments at Hemlo. When the field work for this project commenced in 1983, development trenching allowed for a good view of both the ore subcrop and the nature of the overlying drift. This zone has since undergone open pit mine development and extraction (Werniuk 1986), and hence the overburden cover has been completely stripped away. The geology of the A Zone is summarized by Valliant (1985) who also provides a brief discussion of geophysical and geochemical responses over the zone. The ore zone is approximately 30 m wide and is described as being hosted in quartz-muscovite-pyrite-microcline schists. Gold is stratiform and has a grade of 5.50 g/t.

A detailed account of the geochemical responses over the entire Page Williams Deposit has been reviewed by Gleeson and Sheeham (1984). The current till study benefited significantly from that work and from the assistance of C.F. Gleeson in the field. Permission from Lac Minerals for the reporting of various phases of this project is also gratefully acknowledged.

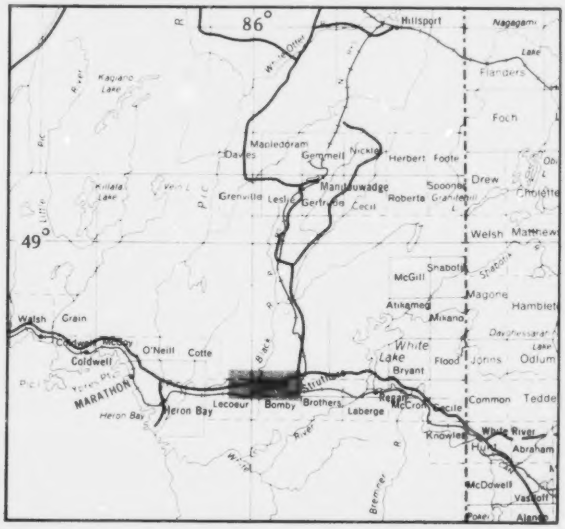
CURRENT STUDY

The till component of the A Zone study consisted of two specific aspects. One was the detailed investigation and sampling of selected sections of the drift in the trench walls which directly overlaid the ore zone. The second part of the study was percussion drill till sampling along two profiles which cross the ore body and which were used for the humus sampling (Figure 037.1). Here the till samples were taken at 1 m intervals on a 10 m hole spacing, using the Pionjar percussion drill and crew provided by Roc Cormier and Associates. Multi-element analyses on both the trench and drill samples were done by the Geoscience Laboratories at the Ontario Geological Survey, Toronto. Based on the initial studies of Gleeson and Sheehan (1984), two sample sizes were analyzed: a minus 80 mesh (0.18 mm) fraction and a minus 250 mesh (0.05 mm) fraction of the till matrix. In addition, carbonate analyses and pebble counts were done on selected trench samples.

Complete details on the analytical results will be forthcoming. The gold values will be reported here in preliminary form, and will be used to illustrate the nature of glacial dispersion and till deposition within the specific context of the Page Williams A Zone.

QUATERNARY GEOLOGY

The surficial cover in the region is composed of a wide variety of Quaternary sediments, all of which exert variable constraints on exploration approaches


86°
49°
Hillsport
Nagagami Lake
Flanders
Foch
Kagiano Lake
Killala Lake
Vein L
Mapledoram
Davies
Gemmell
Nickle
Herbert
Foote
Drew
Manitouwadge
Spooner
Grenville
Leslie
Gertrude
Cecil
Roberta
Cholette
Welsh
Matthews
McGill
Shabotik
Magone
Atikameg
Mikano
Hamblet
White Lake
Flood
Johns
Odlum
Bryant
Walsh
Grain
Coldwell
O'Neill
Cotte
MARATHON
Heron Bay
Lecoeur
Bomby
Brothers
Laberge
Regan
McCron
Cecile
Common
Tedder
Knowles
White River
Abraham
McDowell
Vasiloff
Pic
Little Pic
Black R
White R
Bremner
White Otter

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

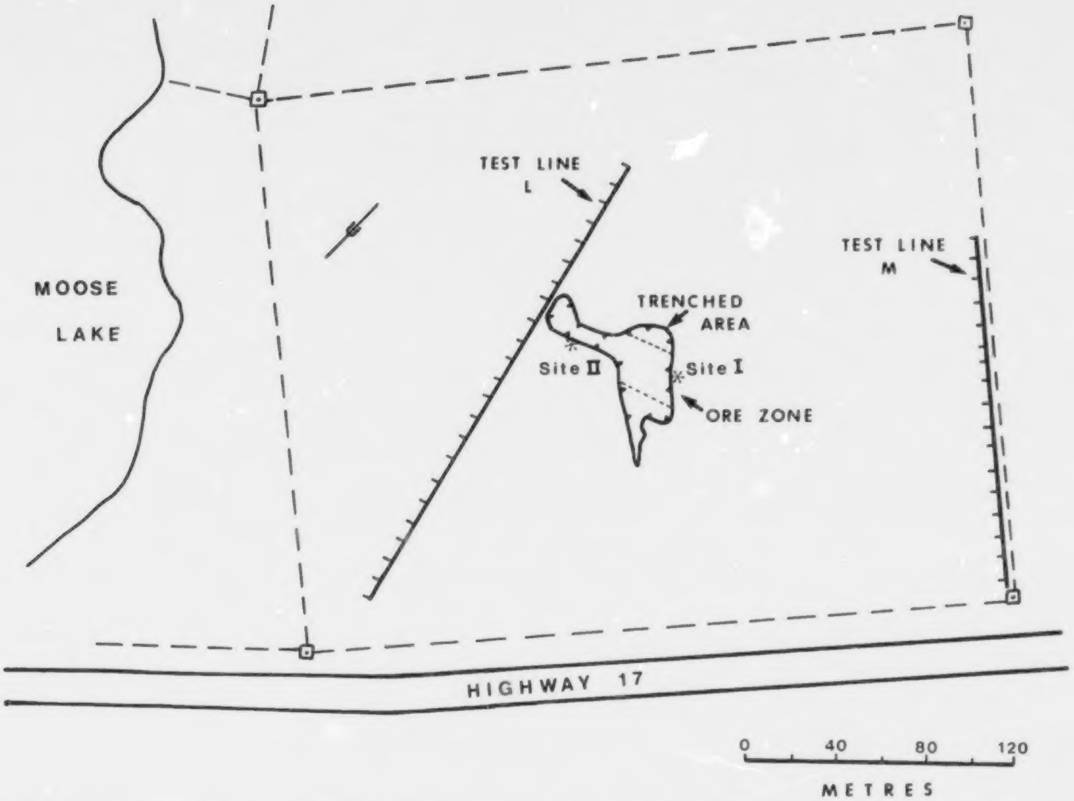


Figure 037.1. *Location of Page-Williams study showing trench area and test lines.*

and technologies (Geddes and Kristjansson 1986). In the direct vicinity of the Hemlo Mine sites, however, the drift cover is relatively thin. The area marks the southern boundary of a complex carbonate-rich till unit which grades into areas of sparse drift and outcrops (Geddes and Bajc 1985).

The pit exposures in the A zone reveal a sequence of several till varieties about 2 m thick in total, and because of the sloping bedrock topography, any variety of till may rest directly on bedrock. Preserved at the base of the till sequence, in only a few, isolated localities, is a cemented, rusty till-like material. Above this, and directly overlying most of the ore zone is a "mixed till", so named because numerous large angular fragments are clearly of local origin (including ore), but the matrix and small pebble component is of non-local or exotic origin. This is clearly shown by an abundance of carbonate rocks, derived from the James Bay Lowland, some 200 km distant. This "mixed" facies grades upwards into material in which the local clast component is lost completely, and the entire till reflects a carbonate-rich exotic nature. This till also shows a highly variable character in texture and structure. It is predominantly clast poor, fine textured and massive, however, some facies show a significant degree of substratification and stoniness.

The uppermost till is much stonier, sandier and, by virtue of an abundance of granodiorite clasts, reflects a more local derivation than the calcareous till beneath it. Some of the uppermost sequence has a sorted or winnowed appearance. This grades downslope and away from the ore zone to a small, basin-shaped pod of laminated glaciolacustrine silts. This sediment likely correlates with the thick lacustrine sequence reported in neighbouring Moose Lake by Gleeson and Sheehan (1984).

ORE ZONE TRENCH SAMPLING

The gold content in the till on two sites directly over the ore zone is displayed in Figures 037.2 and 037.3. Site 1 occurs at the eastern edge of the trench. Here the drift sequence is about 2 m thick, and the soft, schistose ore host appears to extend up into the till sequence. At this site, gold shows a very rapid decrease in content from bedrock into the immediate overlying till. Values drop from 10 000 ppb gold in bedrock, to 100 ppb gold in the material 10 cm above the ore zone. A single high value in the -80 mesh fraction occurs higher up in the section, but this does not have a correponding response in the -250 mesh fraction. With this one exception, the two size fractions reveal very similar patterns, with the -250 mesh fraction being consistently higher in value, although not by a significant factor.

Site II (Figure 037.3) is located in the western sector of the trenched area and shows a very similar response. Again there is a very rapid drop or dilution,

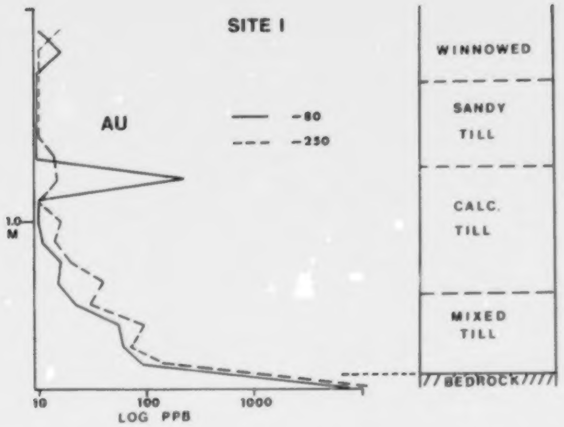


Figure 037.2. Gold content in till above ore zone at site I.

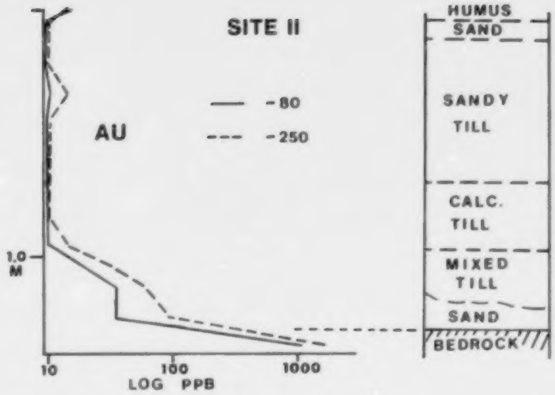


Figure 037.3. Gold content in till above ore zone at site II.

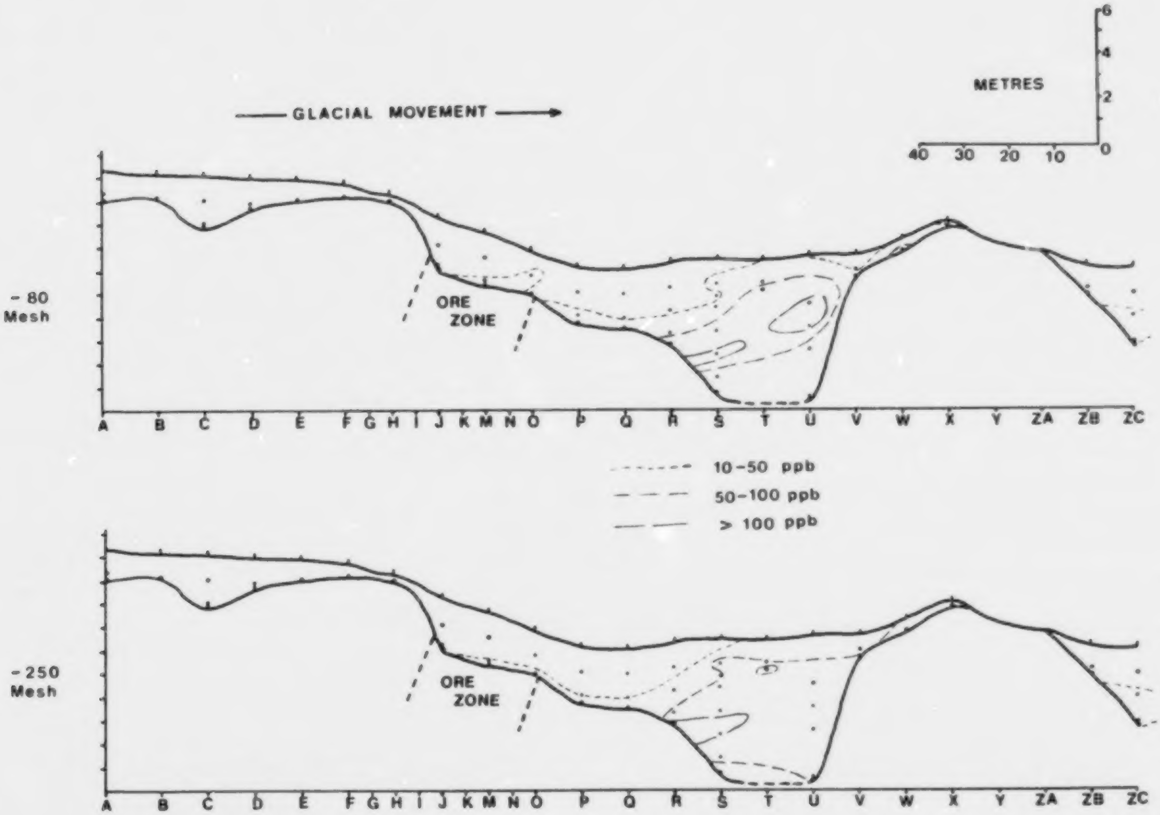

GLACIAL MOVEMENT
METRES
6
4
2
0
40
30
20
10
- 80 Mesh
ORE ZONE
A B C D E F G H I J K M N O P Q R S T U V W X Y ZA ZB ZC
10-50 ppb
50-100 ppb
> 100 ppb
- 250 Mesh
ORE ZONE
A B C D E F G H I J K M N O P Q R S T U V W X Y ZA ZB ZC

Figure 037.4. Gold content in till dispersed in a down-glacier direction from ore zone. Dots denote sample locations.

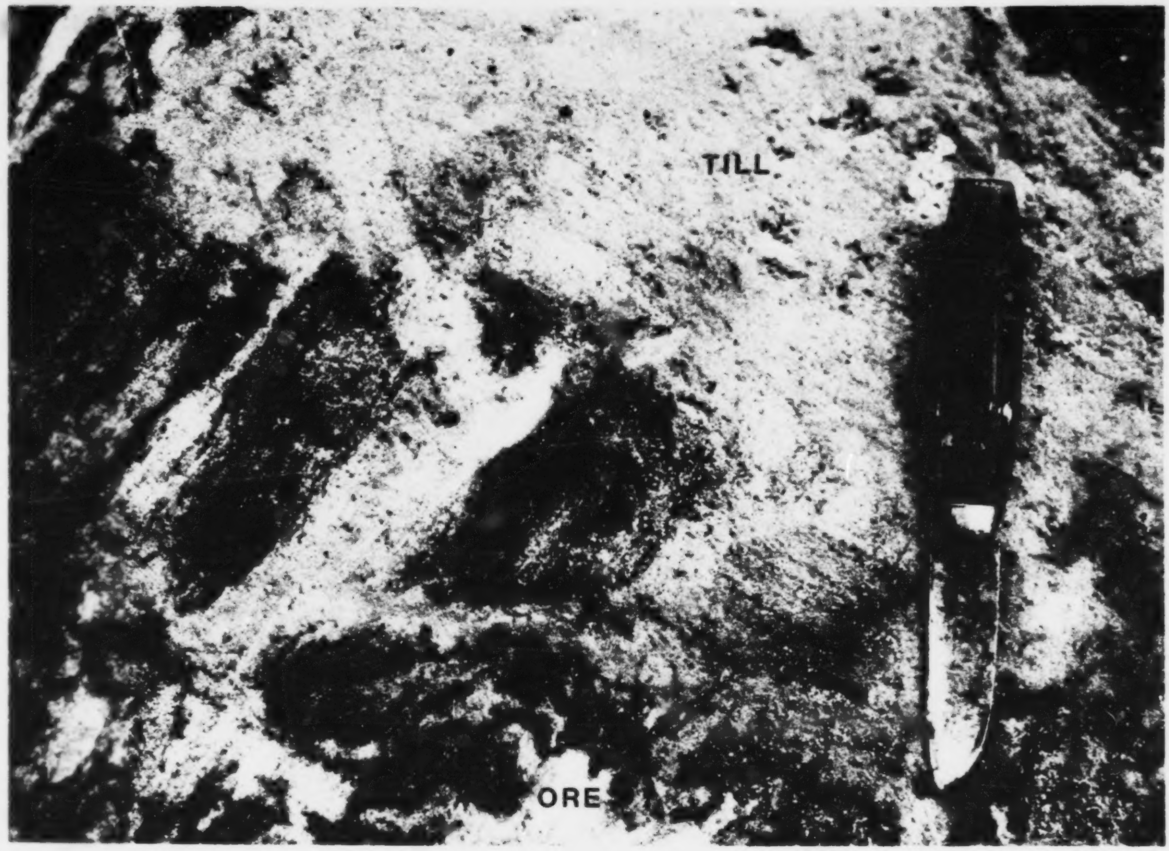


Photo 037.1. *A close-up of till/bedrock interface at trench site I.*

of gold values, which are reduced to near background levels less than 0.5 m above the ore zone.

DRILL PROFILE

The gold content of the till sequence extending in a down-glacier direction is shown in Figure 037.4. Gold dispersion is reflected as a short, yet continuous anomaly which extends from the ore zone in a direction which is both down-slope and down-glacier. An unusual feature of this profile is that the maximum values (roughly 200 ppb gold) occur at a distance between 40 and 60 m from the ore zone itself, giving the dispersion a generally "displaced" appearance. Maximum values do not occur directly over the ore zone, a phenomenon which is confirmed by the detailed trench sampling.

A diffuse anomaly appears to extend for a distance of at least 130 m. It is evident that the bedrock topography, even over this restricted distance, exerts an influence on the shape and nature of the dispersion pattern.

CONTROLS ON GLACIAL DISPERSION

The geochemical patterns revealed by the drill profiles and trench sampling can be used in conjunction with the till mapping of the area to provide an explanation of the glacial dispersion over the A zone. The predominant factors can be discerned from the nature of the till/bedrock interface at the ore zone. A detailed view from trench site I is shown in Photo 037.1.

The friable, schistose ore is not incorporated into the immediate overlying till, and the fragments appear only slightly dislodged or rotated. A greyish, calcareous till matrix appears squeezed into the gaps and fractures at the bedrock surface, and provides a sharp contrast in colour and lithology with the bedrock. Other features of the calcareous till such as structure and compaction indicate that till deposition was dominated by passive, melt-out processes within the inactive base of the glacier. This prevented erosion of the ore zone at the time of emplacement of the overlying till. That the till package was composed of distantly travelled and reworked "exotic" debris, further exaggerates the differences between the ore zone and overlying till.

The profile sampling indicates that glacier erosion of the ore body may have been more active at an earlier stage, but a change in glaciodynamics has caused the dispersion to appear displaced or disjointed. In addition, the relatively short and diffuse nature of the dispersion implies that the abundance of exotic debris has a considerable effect on the entire anomaly. The alkaline nature of the till may also affect the nature of any hydromorphic dispersion. The latter should be considered as the dispersion is downslope from the ore zone and appears better developed in the finer sample size.

CONCLUSIONS

There is a shallow, yet complex, till sequence in the vicinity of the Page Williams A Zone at Hemlo. This sequence is dominated by a calcareous, exotic meltout till, much of which lies directly on the ore zone. The genetic and physical attributies of this till has caused any reflection of local material (ore) to appear displaced and diluted. Thus the pattern of glacial dispersion is atypical of that developed from other case histories which are often cited for use in mineral exploration. Mapping in the area has shown that the carbonate-rich till is extensive and thus must be accounted for in the execution of exploration strategies elsewhere in the Hemlo region.

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038. Quaternary Geology of the Shining Tree Area, Districts of Sudbury and Timiskaming

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

The Shining Tree project area is bounded by Latitudes 47°30′N and 48°00′N and Longitudes 81°00′W and 81°30′W, and includes three 1:50 000 scale map sheets: Sinclair Lake (NTS 41 P/14); Shining Tree (NTS 41 P/11); and Opikinimika Lake (NTS 41 P/6). Quaternary geological mapping and reconnaissance till sampling of the Shining Tree map sheet was undertaken during the Summer of 1986.

The objective of this project is to update and expand the present geological database of the area, for particular application to mineral exploration.

Previous surficial geological work in the project area was completed at reconnaissance scales by Boissonneau (1965) and Roed and Hallett (1979a, 1979b). More detailed Quaternary studies, including bedrock and overburden geochemical investigations, were completed by Closs and Sado (1982) in the Midlothian Lake and Natal Lake areas.

BEDROCK GEOLOGY

Between 1971 and 1976, M.W. Carter mapped the entire Shining Tree map area. All townships, except for portions of Togo, Brunswick, and Londonderry, were mapped at a scale of 1:15 840 (1 inch to 1/4 mile). Carter (1981) provides a regional synthesis and interpretation of the entire area and includes a history of mineral exploration.

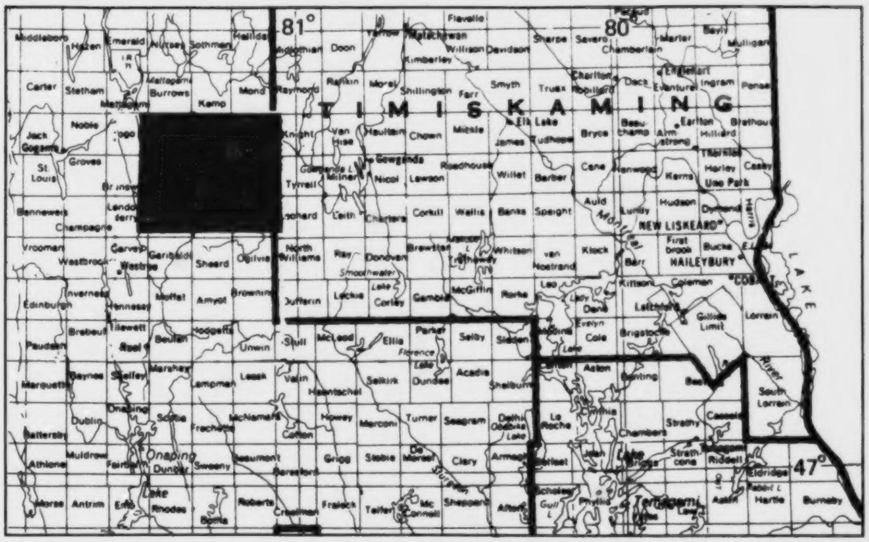
Consolidated rocks within the map area are of Early, Middle, and Early to Late Precambrian age (Carter 1981). Early Precambrian rocks comprise a metavolcanic-metasedimentary sequence, mafic and felsic plutonic rocks, and diabase dikes. Middle Precambrian rocks comprise clastic and chemical sedimentary rocks of the Quirke Lake and Cobalt Groups and intrusive Nipissing-type diabase sills. Early to Late Precambrian diabase dikes cut the previous formations.

Deposits of gold, silver, cobalt, copper, nickel, and iron occur in the area (Carter 1981).

QUATERNARY GEOLOGY

The map area contains a variety of Quaternary deposits that represent the last major ice advance and its subsequent retreat during the Wisconsinan. Glacial striae and other ice flow directional indicators suggest that the last and most dominant ice movement to affect the study area was from the north, at about 185°(±20°) azimuth. Older sets of crosscutting striae ranging between 116° and 150° azimuth and between 200° and 256° azimuth also have been recorded. Older crosscutting striae, of similar orientation to those ranging between 116° and 150° azimuth, were also recorded by Boissonneau (1968) in and beyond the study area. He suggests that these striae represent a readvance of ice from the Chapleau I to the Chapleau II Moraine position (for moraine positions, *see* Boissonneau 1968, p. 100).

Veillette (in press) also records similar older southwest-trending striae, east of the study area. He



LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

suggests that they represent an older regional southwest flow of ice that may be pre-Mid Wisconsinan in age.

Drift thicknesses in the study area are extremely variable, ranging from less than 1 m to more than 50 m. Along the southern edge of the map sheet, and between Granite and Shining Tree Lakes, in Fawcett Township, drift thicknesses usually range between 10 and 50 m. Similar thicknesses were noted in portions of Cabot and Kelvin Townships. With few other exceptions, however, the remaining portions of the study area are characterized by a thin discontinuous veneer of Quaternary sediments over bedrock.

Subglacial till, both melt-out and lodgement facies, is the most widespread Quaternary deposit in the map area. The till is usually thin and discontinuous, with about 20 percent of the underlying bedrock being exposed. In general, the till is a variable stony, silty sand. Locally, both texture and stone content of the till are governed by the lithology and structure of the underlying bedrock.

In section, loose to moderately compact melt-out till commonly overlies a compact lodgement till of similar texture which, in turn, overlies bedrock. In some instances, lodgement till is absent.

Abundant local bedrock lithologies have been found in both till facies, supporting the interpretation that both are of subglacial origin. Exotic indicator lithologies in the till are conspicuously absent in the study area. Apart from very minor amounts of Paleozoic carbonate clasts, probably derived from the James Bay Lowland, no other exotic lithologies were found.

Glaciofluvial ice-contact deposits, consisting of sand and gravel, occur in the form of eskers, esker-kame complexes, end moraines, and other stagnant ice features. Eskers are commonly discontinuous and compound, forming braided systems that usually occupy regional topographic lows. Eskers are also associated with expansive areas of hummocky topography (kames) that occur in the eastern half of the map area: in particular, the Fawcett Lake and Houston Lake areas.

The Chapleau II Moraine position straddles the southern edge of the map area. The moraine consists of poorly sorted sand and gravel that is commonly capped with flow till. These sediments overlie glaciolacustrine silts and sands that, in places, are glaciotectonically disturbed. This observation supports, to a certain degree, the readvance hypothesis proposed by Boissonneau (1968).

Glaciofluvial outwash and deltaic deposits, consisting of sand and gravel in varying proportions, commonly flank and, in some instances, terminate the numerous esker systems in the study area. In particular, these deposits form parts of the east-trending Chapleau II Moraine, at and beyond the southern edge of the map area.

Glaciolacustrine deposits, consisting of silt and sand, form a discontinuous cover over most of the map area. These deposits are generally thin, except in low sheltered areas where thicker accumulations can be expected. For example, glaciolacustrine deposits, up to 15 m in thickness, are exposed along the shores of Mattagami Lake, in the northwestern corner of the map area.

Large parabolic dunes, up to 15 m in height, were found in the northwestern part of the map area. These features are composed of well sorted fine sand and occur between 350 and 380 m above sea level. Their orientation suggests that the paleowind direction was from the northwest.

Recent alluvial deposits consisting of sand, silt, and some organic material, occur sporadically along the margins of most watercourses in the map area. With the exception of the Donnegana River deposits, most are of limited thickness and areal extent and thus are seldom mappable.

Deposits of peat and muck are found in bogs and swamps throughout the area. They occur in bedrock depressions and along the numerous bedrock-controlled streams and rivers. Organic deposits were also found in some kettle holes, particularly those near Fawcett Lake, and on lacustrine sand plains, such as those near Claw Lake.

APPLIED QUATERNARY GEOLOGY

The study area contains known mineral occurrences of gold, copper, lead, zinc, molybdenum, asbestos, nickel, iron, cobalt, and silver (Carter 1981). As well, placer gold occurrences have been reported near Meteor Lake, in the Opikinimika Lake map area to the south. As mentioned earlier, approximately 20 percent of the bedrock is exposed in the study area. Considering the significant proportion of the area that is drift-covered, there is a high probability that other mineral occurrences exist beneath the overburden. Some, in fact, have been found using geophysical techniques.

A reconnaissance till sampling program was initiated to investigate mineral dispersion in the till and to evaluate the effectiveness of sampling this material as a means of prospecting in this area. Preliminary observations suggest that drift prospecting would be a suitable exploration method. However, prior knowledge of the local Quaternary geology is considered critical. Approximately 70 samples of till were collected for geochemical analysis and are being processed.

Aggregate resources are locally abundant in the study area. The existing network of roads is presently adequate for access to aggregate sources for local needs. Demands for aggregate in remote, inaccessible areas may, however, be inadequate. Suitable substitutes, particularly for fill or borrow, are till and some glaciolacustrine deposits.

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039. Quaternary Geology of the Parry Sound Area

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Quaternary mapping of the eastern shore of Georgian Bay was initiated during the summer of 1986. The southern part of the area (i.e. the Lake Joseph (NTS 31 E/4), Sans Souci (NTS 41 H/1), and Parry Sound (NTS 41 H/7 and 41 H/8) map areas) was mapped and is discussed here. Highways 69, 169, 118, and 124 form the major access corridors through the study area, with numerous cottage roads east of Highway 69 providing access to the remainder of the eastern area. West of Highway 69, boat and aircraft provided the best access due to the general lack of roads.

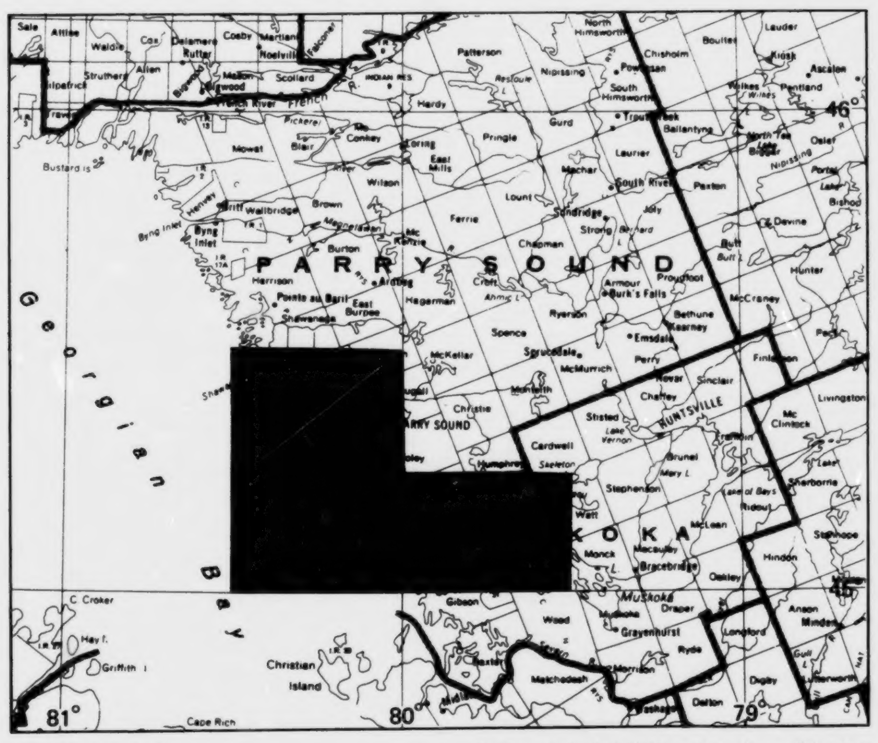
Previous Quaternary mapping of the area is primarily of a reconnaissance nature (Chapman 1975; Chapman and Putnam 1984), with the engineering and terrain studies of Mollard (1980a, 1980b) providing a higher level of detail. Many general and detailed studies of the Lake Huron basin also apply indirectly to the present study area (e.g. Kaszycki 1985). An assessment of the aggregate resources of the Muskoka area (Staff of the Algonquin Region 1983) also includes a portion of the study area. Unpublished reports by Ontario Provincial Parks staff (Haffner and Patten 1971; Spek 1981) present detailed information regarding the geology of two of the Provincial Parks in the study area. An inventory of Georgian Bay Islands National Park (Hirvonen and Woods 1978) provides further detail to a small portion of the present survey.

BEDROCK GEOLOGY

With the exception of North and South Limestone Islands in Georgian Bay, the study area is entirely underlain by strongly foliated gneissic and migmatitic complexes of the Grenville Province of the Canadian Shield (Hewitt 1967). Minor amounts of paragneiss, amphibolite, quartzite, marble and basic intrusive rocks also occur. These rocks are all of Precambrian age. The Limestone Islands represent outliers of Ordovician limestone of the Lower Bobcaygeon Formation (Spek 1981). Carbonate clasts occur in surficial deposits south and southwest of Skeleton Lake, suggesting a local bedrock source in that basin.

QUATERNARY GEOLOGY

The direction of the last (Late Wisconsinan) glacial advance over the region trends south-southwest, with ice-flow indicators, primarily striae, ranging predominantly between 185° to 220° azimuth. A slight fanning effect southwesterly into Georgian Bay is noted.



LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

The Parry Sound area was deglaciated for the last time about 11 500 B.P. (Before Present), at which time it was submerged in an expanding glacial Lake Algonquin. The stagnating ice front retreated rapidly through the area, forming the north and east shores of the Lake. The Main Algonquin lake phase, the highest to form in the basin, was achieved prior to 10 000 B.P. (Eschman and Karrow 1985). At an elevation of about 335 m (1100 feet) above sea level (a.s.l.) (Sharpe, in preparation), the Main Algonquin phase would have submerged the entire map area. Changing outlets subsequently lowered the lake rapidly to the Hough phase, exposing parts of the map area for the first time since deglaciation. A long period of transgression to the Nipissing phase once again inundated much of the map area by about 5500 B.P. Present lake levels were achieved sometime after 3000 B.P. (Eschman and Karrow 1985).

The distribution and thickness of glacial drift in the study area varies greatly. Large tracts of essentially bare bedrock with only minor pockets of sediment dominate west of Highway 69 along the shores of Georgian Bay, and on upland sites throughout the rest of the map area. Surficial deposits, where they occur, typically consist of a thin, discontinuous veneer of stony sand till, and local deposits of ice-contact and lacustrine sediments.

Two till facies have been recognized: a dense silty sand till, with some fissility and minor clasts; and a loose stony sand and silt till with abundant clasts. Both facies are thought to have been deposited as basal melt-out due to the occurrence of stratified sandy horizons throughout the tills. Only in a few areas are the tills substantial enough to mask the underlying bedrock topography. A notable example occurs on Parry Island. Here the tills are poorly bedded, dense, silty sands with sandy and silty interbeds, trending downward into massive silty sands.

Boulder concentrations throughout the study area suggest the former extent of till deposits, the fines having been removed by wave action during the Algonquin and Nipissing submergence. The sandy laminae blanketing some till deposits also suggest reworking by lake waters.

Ice-contact deposits are scarce, scattered, and thin. Local pockets are typically unsorted to layered, of a highly variable texture, and commonly occur in the lee of bedrock ridges perpendicular to the ice-flow direction. Notable exceptions are thick deposits of interbedded sand, gravel and coarse material which mask the bedrock topography on Parry Island. A subaquatic depositional environment is suggested by crude layering and fluvial structures within the ice-contact debris.

Ice-contact subaquatic fan deposits are located in bedrock depressions associated with the Lakes Joseph, Rosseau, and Muskoka basins, their deposition probably confined by ice grounded on local bedrock uplands. These deposits are characterized by highly variable sediments of deformed, laminated sands, silts, and fine gravels, with associated massive sand and diamict flows draped over a fan-shaped core of coarse gravels, cobbles, and sands. They are believed to have been deposited subglacially or near the ice margin into the Main Algonquin lake phase. The fining upward and southward of these deposits reflect the northward retreat of the ice front.

Glaciofluvial deposits occur sporadically in minor bedrock lineaments and pockets throughout the study area. Consisting of crosscut channel-fill sands and gravels with associated ripple-laminated sands and cobble beds, these deposits represent meltwater conduits active after glacial lake levels dropped from their high phases. Some are overlain by subsequent glaciolacustrine deposits, and one small valley-fill deposit on Three Legged Lake is terraced at an elevation of approximately 213 m (700 feet) a.s.l.

Glaciolacustrine valley-fill material and fine-sediment rhythmites occur scattered throughout the study area. The deltaic deposits consist of horizontally stratified sand and fine gravel, often crossbedded, rhythmic, and rippled in nature. These deposits occupy broad, shallow, bedrock depressions, predominantly in the low relief terrain near the shore of Georgian Bay, and probably represent sediment from higher ground to the east redeposited by streams into late, lowering lake phases (as yet unidentified) in the Huron basin. The upper levels of these deposits range in elevation from roughly 253 m (830 feet) a.s.l. north of Parry Sound to about 244 m (800 feet) a.s.l. near Foote's Bay.

Rhythmic sequences of sand, silt, and clay occur in scattered pockets throughout the map area. Local deposits are no more than a few metres thick and are usually capped by a thin, laminated, lacustrine sand unit. Rhythmites of grey-green silt-rich, and red-brown clay-rich units may represent annual varved deposition, as suggested for similar deposits in the Muskoka region (Sharpe, in preparation). The thickness and extent of these deposits generally decrease towards Georgian Bay, reflecting increasing distance from the sediment source during deposition in the Main Algonquin lake phase.

Near Georgian Bay, shallow bedrock depressions contain thin, massive, silt and sand deposits without associated clays or varves. Some of these deposits north of Killbear Provincial Park contain minor amounts of organic remains, including gastropods, mollusks, and some wood remains. The sediments were probably deposited during the Nipissing transgression; identification of the life forms and age dating of the woody remains is required to substantiate this.

Substantial deposits of sand, clay, and boulders are reported from well holes in Killbear Provincial Park, some attaining depths of 49 m (162 feet) (Haffner and Patten 1971). These valley fill materials probably represent a combination of ice-contact and glaciolacustrine sediments. Wind-blown dunes, now stabilized by vegetation, occur on these deposits within the park. Wave-cut terraces and boulder concentrations related to the level of the glacial Lake Nipissing phase were also noted in the park.

The oldest of the Niagara Escarpment rocks are those of the Cataract Group (Lower Silurian). Within this group is the Manitoulin Formation, a thinly bedded dolostone, exploited on Manitoulin Island as a source of building stone. The Middle Silurian deposition began with the units of the Clinton Group. Included in this group are the carbonate rocks: the Neahga, Reynales, and the Fossil Hill Formations. Although usually considered too impure to justify quarrying individually, these units are utilized along with the higher purity material from the overlying Amabel/Lockport Formations. Such operations include the Dufferin Aggregates Quarry at Milton and the Manitoulin Dolomite Quarry on Manitoulin Island. Higher in silica content, these units have some potential for skid resistant aggregate.

Overlying these formations are rocks of the Lockport and equivalent Amabel Formations. These units which form the cap rock of the escarpment are massive to thinly bedded, fine to medium crystalline dolostones which can be richly fossiliferous and cherty. The name Amabel Formation is applied to these beds north of Clappisons Corners and the Lockport Formation to the same strata south of this point. Quarries exploiting these units are prominent in the Milton area, and producers are found as far north as the Bruce Peninsula and Manitoulin Island. Although mostly used for aggregate, zones within this unit have significant potential as a metallurgical flux.

Within the Amabel/Lockport Formations are several thinner bedded intervals, some of which are of sufficient extent to have member status, such as the Eramosa Member in the Wiarton area. This member is worked as a source of building/dimension stone on the Bruce Peninsula. Above the Lockport-Amabel is another significant, producing horizon, the Guelph Formation. This formation is composed of a thinly bedded to massive dolostone. Several quarries to the west of Milton extract from this unit, or from this unit and the Amabel.

SOUTHERN NIAGARA PENINSULA

To the south of the Niagara Escarpment in the Niagara Peninsula, Upper Silurian to Middle Devonian strata have been utilized at several quarries. Production is from the Bertie and Bois Blanc Formations, Detroit River Group, and Dundee Formation strata. Of these units, most production is from the Bertie-Bois Blanc. These materials are primarily used for aggregate. These units contain both limestone and dolostone, with some being quite chert rich and fossiliferous (Bois Blanc Formation).

SOUTHWESTERN ONTARIO

Quarries are found in two main areas of southwestern Ontario: the Woodstock-St. Marys area, and the Windsor area. The Woodstock-St. Marys quarries operate in strata from the Lucas-Amherstburg Formations of the Detroit River Group, and the overlying Dundee Formation. In this area, the high purity of these rocks has permitted their use as a metallurgical flux for steel smelting operations in Hamilton, and for supplying local demand for concrete aggregate. Because of thick overburden cover in southern Ontario, these operations are situated in areas of thinner overburden, such as river valleys.

Quarries in the Windsor area, also utilizing the Detroit River Group strata (Lucas and Amherstburg Formations), have produced high purity stone for flux, even though very high local demand for aggregate has encouraged most operations to supply this market. Heavy demand in the Windsor-Sarnia areas for high purity stone has resulted in interest in sources as far away as Manitoulin Island. This factor initiated a review of these resources in 1979 to 1982 by the Ontario Geological Survey (*see* Johnson 1981).

TIMISKAMING AND JAMES BAY

An outlier of Paleozoic strata is located in the Timiskaming area. As this outlier is located well into the Precambrian Shield, high local demand for lime products has resulted in the fostering of several quarries, although at present only one is active on a full-time basis (Dymond Clay Products Limited). Demand for metallurgical flux stone has led to extraction from the Farr Formation (a calcarenite limestone) and crushed stone for aggregate purposes has also been extracted from the Thornloe Formation (a similar and possibly equivalent unit to the Lockport Formation in the south).

In the James Bay Lowland only one quarry has been opened and that operates only on demand. Designed to supply the original demand for airport runway material, this quarry is used only intermittently and is frequently flooded. Material removed comes from the Murray Island Formation, a fossiliferous limestone. At this time very little is known of the quarry potential of the James Bay Lowland.

FIELD ACTIVITIES

To augment the computerized data file established for this project, field studies provided full, measured, geological sections for each quarry visited, as well as detailed quarry descriptions. Particular attention was paid to active quarries, although abandoned quarries of "geological significance" have also been studied, and will be included in a final report by Derry, Michener, Booth and Wahl Limited, to be published.

The quarries were investigated by R. Wolf, R. Bezys, V. Mazur, M. Johnson, and J. Stevenson. All data has been computer stored and processed.

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044. Aggregate Resources Inventory in Grey County and Northumberland County

R. Gorman[1] and S. Szoke[2]

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INTRODUCTION

Field work was conducted in southern Ontario, during the 1986 field season, as part of the Aggregate Resources Inventory Program. The results of the various field activities will be published in Aggregate Resources Inventory Papers or released in Open File Reports, as applicable. The areas involved in field investigations were:

1. Grey County.
2. Northumberland County.

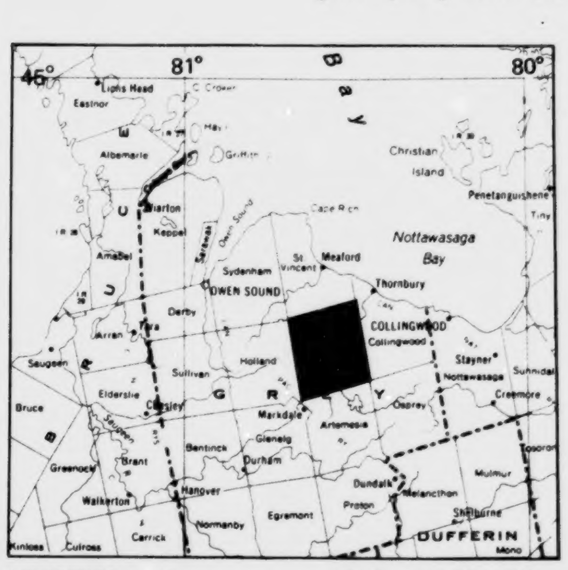
Field investigations consisted of the following activities: examination of potential aggregate deposits, existing pits and quarries, and natural and manmade exposures; and auger drilling. All active and abandoned pits were investigated, and at each site several observations were made, including: face height; percentage of gravel and sand; and the presence of deleterious materials such as chert, shale, clay, silt, and oversized boulders. The intended uses of the granular material and the presence of stockpiles, water-filled ponds, crushing plant, and rehabilitation work were also noted. Estimates were made of the amount of material previously extracted from these pits to enable resource tonnage evaluations to be determined. Active and abandoned quarries were also visited. At these sites, the height of the quarry face was noted, as well as bedrock geology, and the presence of deleterious materials.

The purpose of the field investigations was to confirm and supplement the information gathered from various sources such as existing geological reports and maps, data from the files of the Ontario Ministry of Transportation and Communications, and water well data from the Ontario Ministry of the Environment. In areas where pre-existing data were unavailable or insufficient, representative channel face samples were taken from exposed faces. These samples have been sent to the Ontario Ministry of Transportation and Communications to be analyzed for grain size distribution, soundness, absorption, and lithology (petrographic number or P.N.).

GREY COUNTY

The 1986 field investigation of Euphrasia Township resulted in the completion of field work for Grey County. The preliminary results of the detailed aggregate resource assessment indicate that Euphrasia Township possesses considerably smaller surficial aggregate reserves than townships in southern Grey County.

Glacial ice moved from the Georgian Bay basin in a generally southern direction across the township. The morphology of the Singhampton and Gibraltar Moraines reflects a sublobate pattern of the ice margin as it melted during Port Bruce-Port Huron Stadial times (Feenstra 1978). These moraines are located in the southwestern part of the township. Resources of good quality sand and gravel are concentrated in



LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

ECONOMIC GEOLOGY

For the most part, the map area is lacking in economic aggregate resources. The chief sources of aggregate in the study area are the ice-contact subaquatic outwash fan deposits in the Bala, Port Carling, and Ullswater areas, and the deltaic sand and gravel deposits north of Parry Sound, on Parry Island, and south of Foote's Bay. Numerous small pits identify lesser deposits of glaciofluvial, ice-contact, and glaciolacustrine origin. In addition to being too small, most deposits in the map area are either too fine-grained, or contain too much over-sized material to be economically important.

RELATED RESEARCH

C. Vasko is completing a B.Sc. thesis, at the University of Waterloo, based on a detailed inventory of the carbonate dispersal train south and southwest of Skeleton Lake. At least 3 types of carbonate rocks and a granitic breccia have been identified in the clast content of glaciofluvial deposits, and in scattered till sections, "downstream" from the suspected meteorite impact basin of Skeleton Lake, for a distance of up to 20 km. Bedrock sources for the Paleozoic sediments were not identified, but may occur as outliers in the basin under the present lake level. A possible source for the breccia was identified on the northwest shore of Skeleton Lake.

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040. Quaternary Geology of the Eastern Halves of the Barrie and Elmvale Areas, Simcoe County

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INTRODUCTION

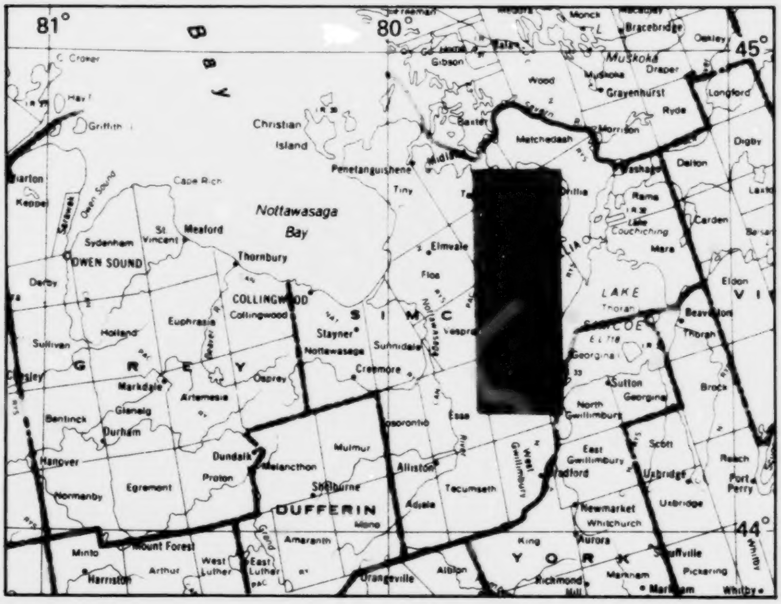
The project area is located between 44°15'N and 44°45'N Latitude, and 79°30'W and 79°45'W Longitude. This area is portrayed on the eastern halves of the Barrie (31 D/5) and Elmvale (31 D/12) 1:50 000 scale National Topographic Series (NTS) maps.

The Pleistocene geology of this area has been previously mapped at a scale of 1:126 720. It was part of a much larger study area that was mapped in the late 1940s by the Geological Survey of Canada. A report entitled "Pleistocene Geology of the Lake Simcoe District, Ontario" was published (Deane 1950). In his study, Deane concentrated on the landforms and surface sediment characteristics and distribution, with particular attention being paid to shoreline features and deposits of the ancestral proglacial lakes in this area.

The present project is designed to map the surficial sediment in greater detail (1:50 000 scale) and to obtain information and a better understanding of the sediment distributions and relationships at depth. This area contains several known occurrences of buried mineral aggregate. However, at present little is known of their origin and subsurface extent.

During the past summer, two weeks were spent in the study area. Several reference sections were established and representative material from them was sampled for laboratory analysis this fall. A general overview of the geology of this area was also obtained. Some interesting preliminary findings include:

1. Solution weathering of the Paleozoic rock formations in the northern part of the study area is extensive, and consists primarily of minor solution-sculptured forms (Karren). Grikes (solution-widened joints), solution runnels, and solution pipes are the common forms present on exposed, or on discontinuous, thinly covered limestone surfaces. In recently uncovered limestone surfaces such as at the Uhtoff Quarry (UTM 1880 4865, NTS 31 D/12), the freshly exposed limestone surface is well striated and polished. Rat tail striae and chattermarks within striae indicate glacial ice movement towards the southwest (average 213°N azimuth). Development of sichelwannen (sickle-shaped erosion forms), attributed here to subglacial meltwater erosion, is limited and consists of the occasional shallow scallop 1 to 2 cm deep and about 40 cm long. The final form of the rat tail striae may have also been augmented by subglacial meltwater erosion (D.R. Sharpe, Geological Survey of Canada, Ottawa, personal communication, 1986). Down-ice flow direction plucking, and smooth, striated, up-ice facing edges of rock fractures and grikes indicate that the solution-sculptured forms were formed prior to the emplacement of the till and the subglacial erosion. Infilling of grikes by diamicton (squeezed-in till) at this quarry and at the Coldwater Quarry (UTM 0965 5062, NTS 31 D/12) also support a pre-till origin


81°
80°
45°
44°
BAY
Christian Island
Penetanguishene
Nottawasaga Bay
Elmvale
Thornbury
Meaford
OWEN SOUND
COLLINGWOOD
Stayner
Creemore
S I M C O E
G R E Y
LAKE SIMCOE
Bracebridge
Gravenhurst
Muskoka
Orillia
Sutton
Newmarket
Aurora
Alliston
Shelburne
Dundalk
Durham
Hanover
Mount Forest
Orangeville
DUFFERIN
Y O R K
Uxbridge
Port Perry
Whitby
Markham
Richmond Hill

LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

for some of the solution-sculptured forms. The till at the Uhtoff Quarry is heavily cemented in its lower portion, indicating that most post-glacial surface solution activity at this site is occurring within the till (soil zone).

Beneath the till, grikes were observed up to 1 m wide and one such grike extended to greater than 1 m down below the bedrock surface in the Coldwater Quarry. Solution pipes, which may indicate greater solution forms at depth, were observed up to 1.5 m in diameter. Minor collapse of thin-bedded units within solution cavities was observed along quarry walls.

2. At least three units of subglacial till are present in the upland areas. Each is associated with a glaciolacustrine sediment sequence, suggesting that whenever the glacial margin was in the area, ponding of meltwater occurred in front of it. With the exception of the uppermost till layer, the tills appear to be truncated by the large, steep-walled, presently "U"-shaped valleys that cross the study area. The uppermost till drapes the surface of the landscape, occurring along valley walls and on the upland surface, and hence, is contemporaneous or post-dates the cutting of these deep valleys.
3. These deep, steep-walled valleys form part of a larger system that occurs essentially between the Niagara Escarpment and the Precambrian Shield. They could have been cut subaerially prior to the last glacial advance in the area, at a time when the water level in the Lake Huron basin was low, during the Mid-Wisconsinan (?) or Sangamonian (?). However, they could possibly represent a network of tunnel valleys carved during the last glacial event by the rapid release of meltwater ponded beneath the glacier. The streamlined surface of the uppermost till unit in the upland areas complements this mechanism (*see* Wright 1973; Shaw 1983; Shaw and Kvill 1984). Large volumes of meltwater could have been ponded beneath the glacier located in the lowland areas in front of the Niagara Escarpment and/or the Black River Escarpment, and then burst catastrophically (Jökulhlaup), forming these large "U"-shaped valleys. In the interfluves, the casts for the drumlins could also have formed at this time or immediately prior to tunnel valley formation. Deane (1950) suggested that these valleys may represent the location of late-stage, narrow, ice tongues. Further investigation is needed to determine which of these hypotheses of valley formation is most likely.
4. The Bass Lake Kame Moraine (Deane 1950) or the Oro Moraine (Chapman and Putnam 1984) appears to be composed of coalescing sub-aqueous fans. Active ice was present along the northern, eastern, and southern margins of this feature, contrary to Deane (1950), who suggested the ice was only on the northern side.

Field investigations in the Barrie-Elmvale area were undertaken with the assistance of Ross I. Kelly and Robert J. Delorme. Rob Delorme has undertaken, as a thesis at the University of Western Ontario, a sedimentological study of one of the fans that make up the Oro Moraine.

Additional field work in the Elmvale area is planned for next summer.

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041. Quaternary Geology of the Brampton Area

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INTRODUCTION

Of the six weeks spent mapping the Brampton area in 1986, three and one half weeks were spent completing the mapping of the west half of the area, principally in the Halton Till Plain between Georgetown and Brampton. Since a preliminary map with marginal notes for the west half of the area has been submitted to the Ontario Geological Survey for publication it will not be discussed further here. Field work summaries for 1984 and 1985, for parts of the west half, have been previously published (Karrow 1984, 1985).

BEDROCK

The western portion of the newly mapped part of the study area (Brampton, Malton, Streetsville) is underlain by red mudstone of the Queenston Formation (Ordovician), whereas the eastern portion is underlain by grey shale of the Georgian Bay Formation. Small outcrops occur along Etobicoke Creek, Spring Creek, and Mimico Creek near Brampton and Malton. More extensive shale cliffs occur along the Credit River near Streetsville. Over much of this area, Quaternary deposits are only a few metres deep. Major exceptions are the deeper deposits over buried valleys at Meadowvale, under the Brampton Esker (Karrow *et al.* 1977), and near the Humber River.

A brick plant at Streetsville is the only currently active extraction operation based on bedrock resources.

QUATERNARY DEPOSITS

The principal surface material is gritty, clayey silt Halton Till, which varies from brown in the west to olive buff or drab grey-brown in the east. The colour variation reflects the incorporation of differing bedrock in those parts of the area.

Also quite extensive at the surface are glaciolacustrine deposits of silt and clay, with grits and pebbles, and considerable interbedded diamicton. The principle area of such deposits is north and east of Malton, where well stratified thicker, deposits are present. The Halton Till extends everywhere under these deposits and is exposed in valley sides.

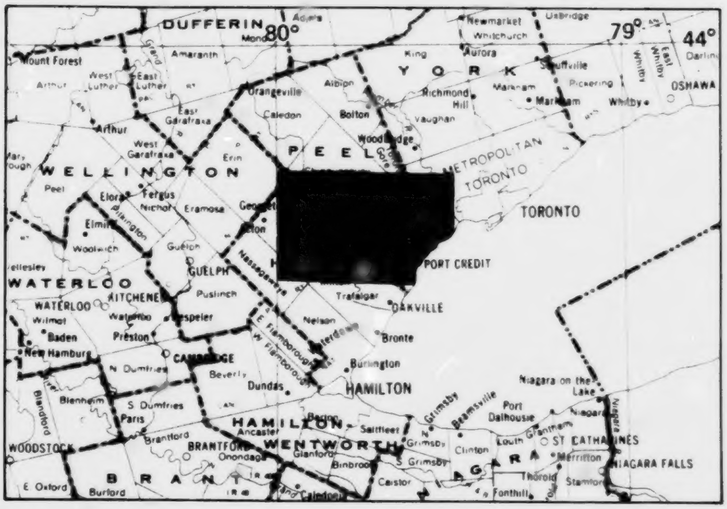
Deltaic sand and gravel deposits occur along the Credit River valley near Meadowvale, and similar but areally small deposits occur along Etobicoke Creek, southeast of Brampton.

Kettle bogs, associated with the Brampton Esker, are the only organic deposits so far encountered. They occur in eastern Brampton and extend from the north edge of the map area to about 1 km south of Steeles Avenue.

Older terrace alluvium (sand and gravel) occurs on terraces above the present flood plain along the Credit River near Streetsville. Near Streetsville, the modern floodplain of the Credit River becomes constricted, as bedrock cliffs form the valley walls. In contrast to the Georgetown area, the buried valley of the Credit is east of the present river at Streetsville. The buried valley and the present valley apparently cross near Meadowvale.

ECONOMIC GEOLOGY

A few small abandoned gravel pits represent the only exploitation of Quaternary deposits in this part of the area. They occur in older terrace deposits of the Credit River near Streetsville and in the south end of the Brampton Esker. Extensive shallow drift, and general inaccessibility of deeper deposits, make prospects of exploitation poor.


DUFFERIN
80°
79°
44°
Mount Forest
Amaranth
West Luther
East Luther
Arthur
Orangeville
Albion
Caledon
Bolton
East Garafraxa
West Garafraxa
Erin
PEEL
Woodbridge
WELLINGTON
Peel
Elora
Fergus
Nichol
Eramosa
Elmira
Pilkington
Woolwich
Guelph
GUELPH
Wellesley
WATERLOO
KITCHENER
WATERLOO
Waterloo
Hespeler
Puslinch
Nassagaweya
Trafalgar
Nelson
Wilmot
Baden
Preston
New Hamburg
N Dumfries
CAMBRIDGE
Beverly
E Flamborough
W Flamborough
Dundas
Burlington
HAMILTON
Bronte
OAKVILLE
PORT CREDIT
TORONTO
METROPOLITAN TORONTO
Newmarket
Whitchurch
Uxbridge
King
Aurora
YORK
Stouffville
Richmond Hill
Vaughan
Markham
Pickering
Whitby
East Whitby
OSHAWA
Blandford
Blenheim
S Dumfries
Paris
Brantford
BRANTFORD
Onondaga
Ancaster
HAMILTON
WENTWORTH
Glanford
Binbrook
Saltfleet
Grimsby
S Grimsby
Beamsville
Clinton
Port Dalhousie
Louth
Grantham
ST CATHARINES
Merritton
Niagara on the Lake
Niagara
NIAGARA FALLS
Thorold
Stamford
Fonthill
Caistor
NIAGARA
WOODSTOCK
E Oxford
Burford
BRANT
Caledonia

LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

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042. Mid–Ontario Building Stone Project, Bruce Peninsula

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (E[illegible]) signed by the governments of Canada and Ontario.

INTRODUCTION

During the summer of 1986, field work was conducted on the Bruce Peninsula as a part of the COMDA funded Mid-Ontario Building Stone Project. The overall objective of this project is to evaluate the dimension/building stone potential of strata in the Bruce Peninsula and Parry Sound areas. The study in the Bruce Peninsula is centred on the Eramosa Member of the Amabel Formation.

Field work was divided into two parts: (1) active and abandoned quarries of the Eramosa were investigated to identify and delineate immediately accessible resources; and (2) reconnaissance mapping was conducted to investigate the regional extent of this resource.

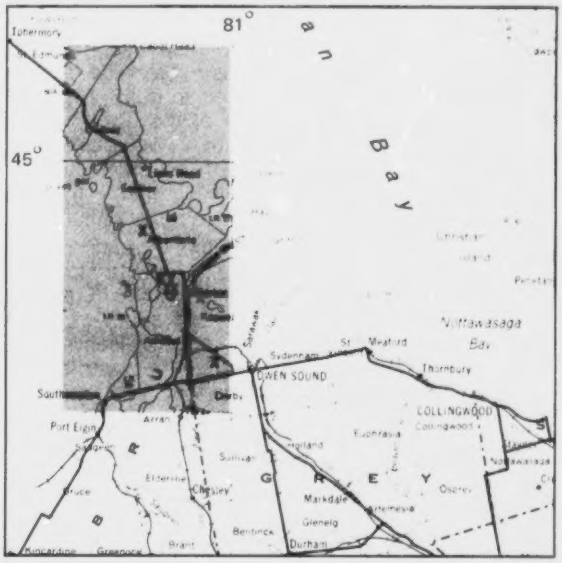
LOCATION

The entire Bruce Peninsula study area is accessible by Highway 6 via Owen Sound and is covered by 1:50 000 NTS map sheets of Wiarton (41 A/11), Cape Croker (41 A/14), and Dyer Bay (41 H/3). The locations of the quarries investigated in this study are indicated on the location map.

GENERAL GEOLOGY

Bolton (1953, 1957) subdivided the Middle Silurian Amabel Formation into four members of which the Eramosa Member is the uppermost. Liberty and Bolton (1971) combined the middle two members of the Amabel Formation into one member (the Wiarton/Colpoy Bay) and included the Amabel Formation as the uppermost member of the Lockport Formation. In this report the Eramosa Member is considered to be the uppermost member of the Amabel Formation, overlying the Wiarton/Colpoy Bay Member and underlying the Guelph Formation (Figure 042.1). The Eramosa consists of thin-bedded, grey to dark grey, brown to dark brown, finely crystalline, bituminous dolostone interbedded with thin bedded non-bituminous dolostone. The Eramosa is interpreted to be an inter-reefal facies associated with Amabel bioherms of the Wiarton/Colpoy Bay Member (Bolton 1953, 1957) and in part with the lower Guelph bioherms (Liberty and Bolton 1971).

The Eramosa's upper contact with the Guelph Formation is taken at the base of thick (1 to 5 m) massive beds of brown, finely crystalline, dolostone which may include minor thin bituminous partings (Liberty and Bolton 1971). Its lower contact is less well de-


81°
45°
Tobermory
St. Edmunds
Bay
Christian Island
Nottawasaga Bay
Sarawak
St. Vincent
Meaford
Sydenham
OWEN SOUND
Thornbury
COLLINGWOOD
Collingwood
Southampton
Derby
Arran
Port Elgin
Saugeen
Euphrasia
Holland
Sullivan
Nottawasaga
Elderslie
Chesley
G R E Y
Osprey
Bruce
Markdale
Artemesia
Glenelg
Bentinck
Brant
Durham
Kincardine
Greenock
B R U C E

LOCATION MAP
x Eramosa quarry locations

Scale: 1:1 584 000
or 1 inch to 25 miles

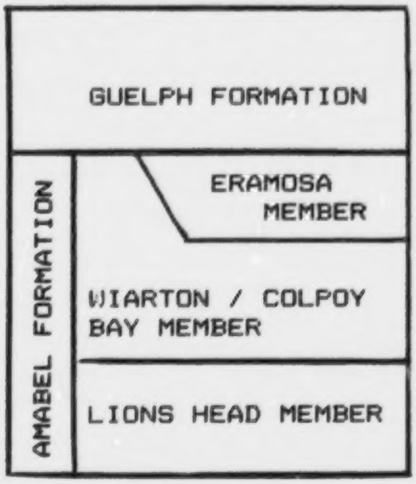


Figure 042.1. *Amabel and Guelph stratigraphy on the Bruce Peninsula (after Bolton 1957, and Liberty and Bolton 1971).*

fined because of its contemporaneous, at least in part, deposition with Amabel bioherms.

Although there is no published distribution map of the Eramosa Member, Liberty and Bolton (1971) report occurrences of the Eramosa on the Bruce Peninsula from Shallow Lake (south of Wiarton) north to Brinkman Corners (north of Lions Head). Because Eramosa deposition is directly related to Amabel biohermal accumulation (Liberty and Bolton 1971), it is absent where Amabel bioherms grade upwards into Guelph strata.

1986 FIELD WORK

Active and abandoned quarries on the Bruce Peninsula afford good exposures of the Eramosa Member at various stratigraphic levels. Three lithotypes within the Eramosa have been identified at these localities:

1. Laminated, thin-bedded, grey to dark grey or brown to black, finely crystalline bituminous dolostone, locally stromatolitic, with local beds or nodules of chert.
2. Thin- to medium-bedded, light buff-brown to brown, fine to medium crystalline, non-bituminous to moderately bituminous dolostone, with locally abundant vugs (leached corals or brachiopods), locally abundant small brachiopods, and variable amounts of dark brown, wispy, branching laminae/stylolites and minor local chert.
3. Transitional between (1) and (2)—thin-bedded, light brown to brown dolostone with dark brown, wispy laminae/stylolites coalescing into thin (less than 3 cm) shaly bands.

Lithotypes 1 and 2 are consistent with those previously described for the Eramosa by Bolton (1953, 1957).

A schematic composite section (Figure 042.2) was constructed from intervals of the Eramosa exposed in the quarries along Oliphant Road, immediately northwest of Wiarton. The Eramosa's upper contact with the Guelph Formation was recognized in Cook Quarry (currently abandoned) on the north side of Oliphant Road (Liberty and Bolton 1971). The basal contact of the Eramosa with underlying Amabel Formation members is not exposed in this area, so the total thickness of this member can only be approximated at 12 to 16 m.

The Eramosa can be subdivided into four units based on the stratigraphic distribution of the above three lithotypes (Figure 042.2). The lowermost unit (1) consists predominantly of lithotype 2 with locally developed beds of lithotype 3. The total thickness of unit (1) is unknown owing to the lack of an exposed basal contact, however, up to 1.5 m of this unit is locally exposed in the study area. Unit 2 consists of 2.4 to 3.7 m of grey to dark grey, wavy to planar laminated lithotype 1. Unit 2 is overlain by 2.4 to 3.0 m of lithotype 2 with minor lithotype 3 beds comprising unit 3. Unit 4 may be up to 8 m thick and consists of interbeds of all three lithotypes. Local bioclastic beds and proximity to Guelph bioherms suggests at least partial contemporaniety of unit 4 with the Guelph bioherms.

Excavations in most of the active Eramosa quarries have exposed units 2 and 3. Only in those quarries on Oliphant Road is the complete sequence from unit 1 through 4 exposed. However, unit 1 was discovered in drill core from the southernmost quarry, and unit 4 was discovered in an outcrop east of the quarry immediately southeast of Wiarton.

Unit 2 generally contains minor stromatolitic intervals most notably towards its base and at the upper contact. In the northernmost quarry unit 2 is significantly more stromatolitic.

Regional reconnaissance mapping has focused on the previously mapped (Liberty 1966) Guelph/Amabel contact. Quarry excavations subsequent to earlier mapping have exposed a more complete Eramosa reference section (Figure 042.2) which can be used to guide regional mapping. The interbedded nature of the Guelph/Eramosa contact and the presence of a Guelph-like facies (lithotype 2) near the base of the Eramosa indicate that the Eramosa may actually lie above the mapped Guelph/Amabel contact.

In most cases, regional investigations have extended Eramosa stratigraphy beyond the current quarry properties. Eramosa lithotype 1 has also been discovered south of Wiarton, in the vicinity of Hepworth, west of Hepworth (or Mountain) Lake. Reconnaissance mapping is continuing on the Bruce Peninsula north of Wiarton.

ECONOMIC GEOLOGY

Commercial interest in building stone from the Bruce Peninsula has recently increased with the awarding of a multi-million dollar contract to Arriscraft Corporation to supply facing stone for the new Canadian Embassy in Washington. Arriscraft is supplying over 3000 tonnes of building stone from the Wiarton/Colpoy Bay Member of the Amabel Formation extracted from its quarry north of Wiarton.

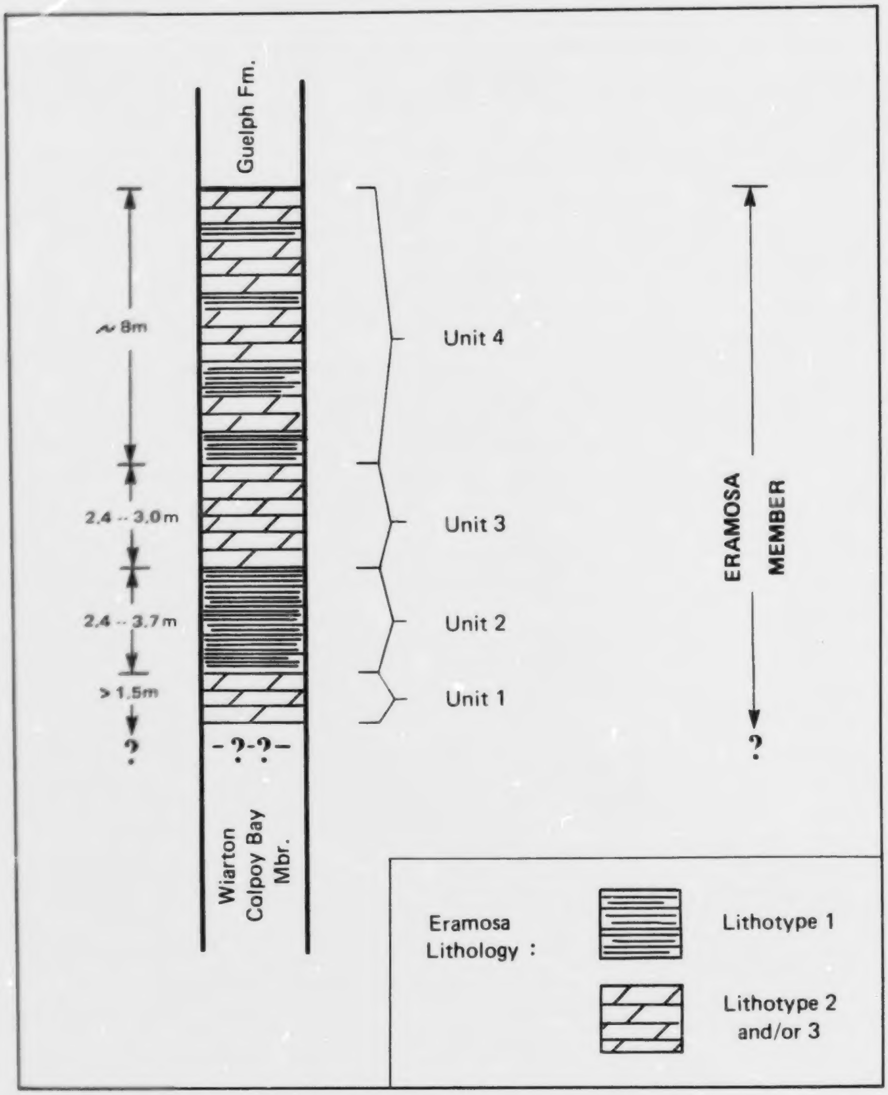


Figure 042.2. *Schematic composite section of the Eramosa Member at Oliphant Road northwest of Wiarton.*

The Eramosa Member on the Bruce Peninsula is quarried for a variety of products. Lithotypes 2 and 3, in units 3 and 4, yield products including drywall and retainer wall blocks, ledgerock, cut patio stone, random flagstone, hearths, sills, and lintels. These products are generally guillotined or sawn at the quarry sites.

Eramosa lithotype 1 in unit 4 is quarried for random or cut flagstone or ledgerock.

Unit 2 is locally referred to by Eramosa quarry operators as the "Marble". Where it outcrops, subcrops beneath surficial deposits, or is covered by less than 2 m of the more massive unit 3 beds, the "Marble" separates into 2 to 5 cm beds and is quarried for random or cut flagstone or ledgerock. Where the "Marble" beds are covered by more substantial strata, partings or separations are less frequent, yielding blocks of sufficient thickness for polished dimension stone (i.e. greater than 40 cm thick). When polished on a plane perpendicular to the bedding plane, beds must usually be at least 40 cm thick (depending on building specifications), and when polished parallel to the bedding plane, beds must be at least 10 cm thick (depending on the amplitude of bedding warp). Large (approximately 1 m^3) blocks of "Marble" with solution enhanced joint facies are quarried for "landscape" or "waterfall" stone.

Mapping outside existing active quarry properties indicates additional potential Eramosa reserves.

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043. Limestone Industries Study of Ontario

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INTRODUCTION

In response to an industry demand for an up-to-date comprehensive report on the Limestone Industries of Ontario, a study was initiated by the Aggregate Resources Section, Ministry of Natural Resources. The project is an update of previous reports by Hewitt (1960, 1964) and Hewitt and Vos (1972).

The overall project has been contracted to Derry, Michener, Booth and Wahl Limited with the geological component being carried out by the staff of the Paleozoic/Mesozoic Geology Subsection of the Engineering and Terrain Geology Section.

Early in 1986, a computer access inventory was compiled of all licenced and abandoned limestone and dolostone quarries in Ontario. Quarrying of limestone and dolostone in Ontario is restricted to southern and eastern Ontario, with minor operations on Manitoulin Island, and in the Timiskaming area and the Moose River Basin (*see* Location Map). During the field season of 1986, geologists of the Paleozoic/Mesozoic Geology Subsection visited all of the active and licenced quarries to provide a geological base for this study. In addition, visits were made to many of the abandoned quarries. The original computer quarry inventory contained over 600 quarries, 200 of which are licenced operations. Approximately 120 of these operations are considered to be major operations.

The quarries expose various sections of Paleozoic rocks ranging in age from Lower Ordovician to Upper Devonian. The final report for this project will contain geological descriptions and sections for individual quarries and a regional chapter summarizing the full Paleozoic stratigraphic succession and structural geology of southern and eastern Ontario.

The distribution of limestone quarries in Ontario (including dolostone) is a function of varying local demand, overburden thickness, and bedrock type. However, their distribution can be broken down geologically, from east to west, into five main areas as follows: Eastern Ontario, Central Ontario, Niagara Escarpment, Southern Niagara Peninsula, and Southwestern Ontario. As the regional dip of the rocks is to the southwest, these five main areas expose progressively younger rocks toward the southwest. A sixth area to the north, the Timiskaming-James Bay area, is also included.

EASTERN ONTARIO

This area is defined as being east of the Frontenac Axis, a Precambrian ridge which cut the Paleozoic rocks, east of Kingston (*see* Figure 043.1) and includes rocks of Lower to Middle Ordovician age. Due to the continued high local demand for aggregate and building stone, this material has been mined from over 100 quarries in the Ottawa area alone. The material quarried, comes from the Beekmantown Group (Oxford and March Formations), a sequence of dolostones and sandy dolostones of Lower Formation Ordovician age, and the Simcoe Group, a sequence of limestones, dolostones, and shales of Middle Ordovician age. Rocks of the Beekmantown Group are restricted to the eastern Ontario area whereas, the Simcoe Group rocks are found across central Ontario (*see* Figure 043.1).

CENTRAL ONTARIO

Within central Ontario there is a sequence of strata ranging in age from the Middle to Upper Ordovician. Included therein are rocks from the already mentioned Simcoe Group, and the overlying Upper Ordovician Blue Mountain, Georgian Bay, and Queenston Formations. Except in local cases, the Upper Ordovician strata are not used as a source rock for Ontario's limestone industry. The basal formation of the Simcoe Group is the Gull River Formation. These strata outcrop/subcrop in the Kingston area and have long been used by the limestone industry.

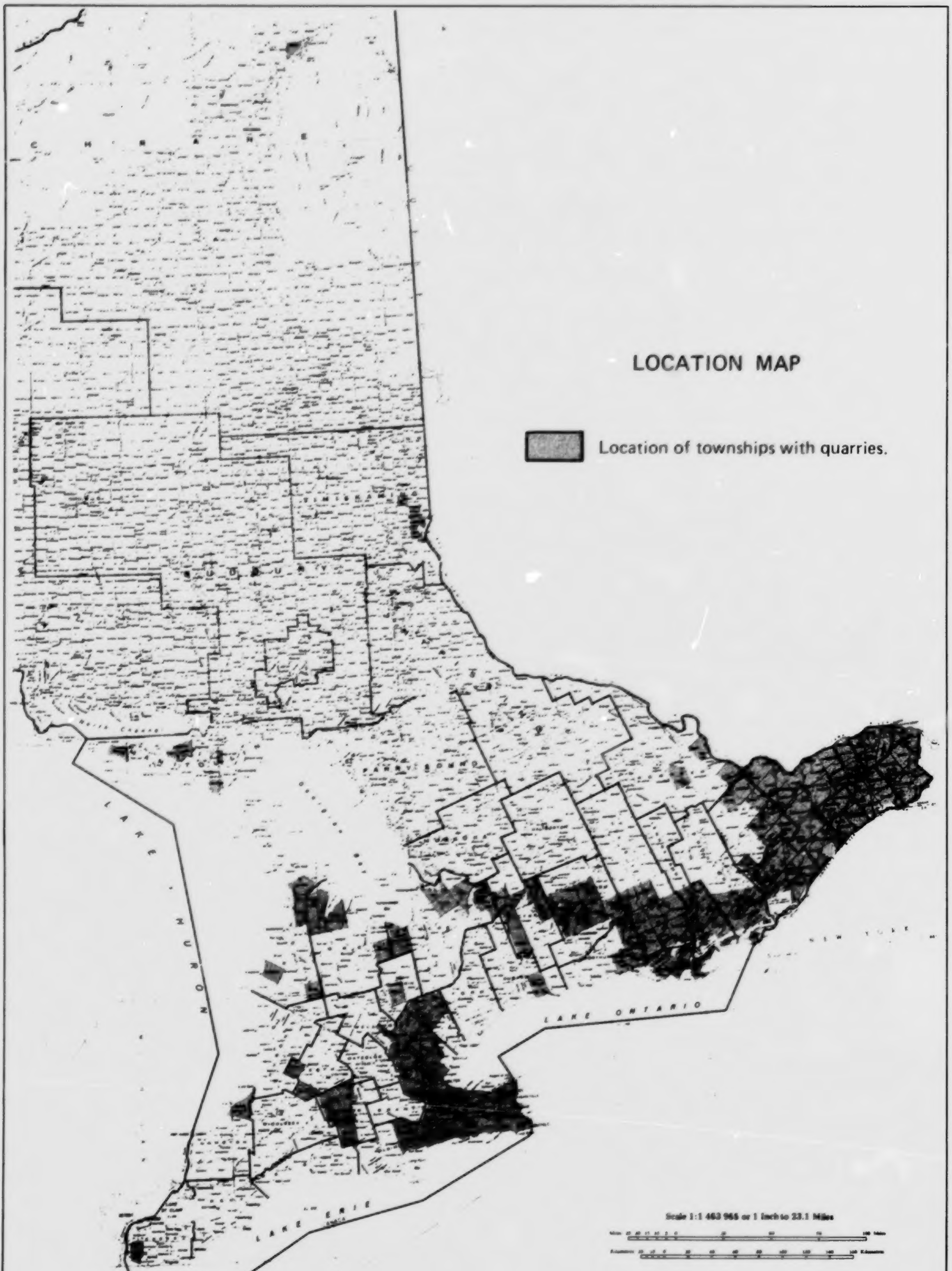
The Gull River Formation consists of finely crystalline limestone, lithographic limestones, and dolomitic limestones, and is well exposed in the Coldwater Quarry in Medonte Township, and the Marmora Pit at Marmora.

The immediately overlying Bobcaygeon Formation consists of fine to medium crystalline limestones and has long been an aggregate producing formation. It is well exposed in the Brechin Quarry near Lake Simcoe.

Overlying the Bobcaygeon is the Verulam Formation, a thinly bedded, shaly, sometimes bioclastic limestone; and the Lindsay Formation, a thinly bedded, nodular limestone. The Lindsay and Verulam are found in the area between Prince Edward County and Bowmanville, stretching north to Georgian Bay (*see* Figure 043.1). Although utilized for aggregate production, both units are better known as source rocks for the manufacture of cement. In general, these units are not of sufficient purity to be used as metallurgical flux. Because of the thick overburden cover, very few quarries are encountered between Toronto and the Belleville area. Several quarry operations are found northeast of Toronto, in the Lake Simcoe and Peterborough areas.

NIAGARA ESCARPMENT

As the major physiographic feature in the Great Lakes area, this north- and east-facing cuesta exposes Lower and Middle Silurian strata ranging from the Manitoulin Formation through to the Guelph Formation. Extending in an arc through Manitoulin Island, the Bruce Peninsula, and across the Niagara Peninsula, this feature has made available to the limestone industry several units which may otherwise be buried under overburden.


LOCATION MAP
Location of townships with quarries.
COCHRANE
SUDBURY
PARRY SOUND
LAKE HURON
LAKE ONTARIO
LAKE ERIE
NEW YORK
Scale 1:1 463 955 or 1 inch to 23.1 Miles
Miles
Kilometres

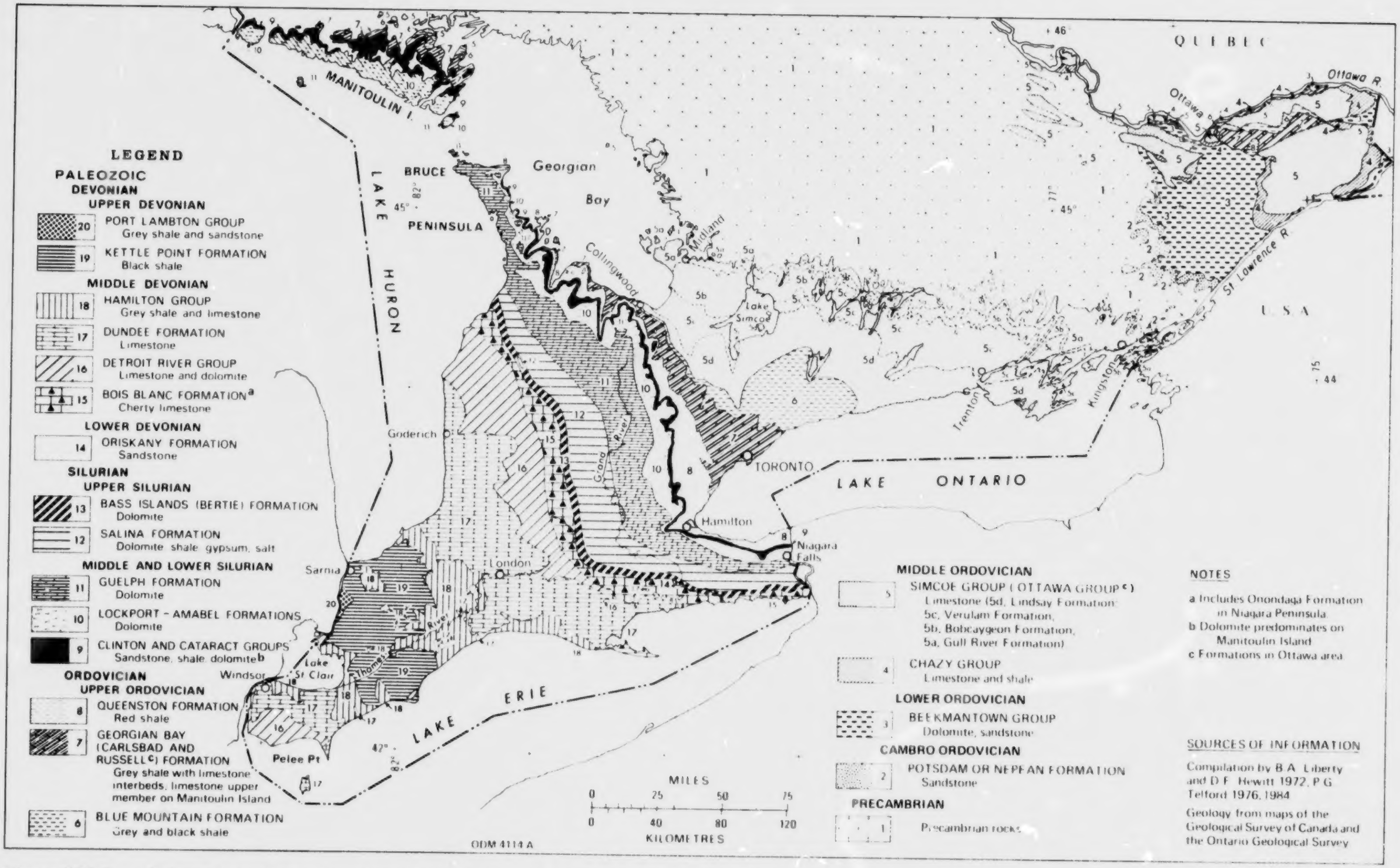
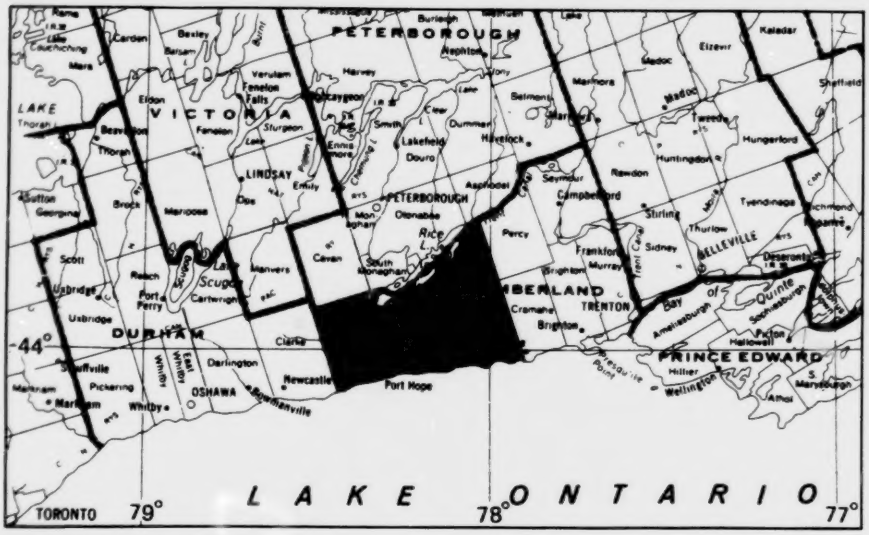

LEGEND
PALEOZOIC
DEVONIAN
UPPER DEVONIAN
20 PORT LAMBTON GROUP
Grey shale and sandstone
19 KETTLE POINT FORMATION
Black shale
MIDDLE DEVONIAN
18 HAMILTON GROUP
Grey shale and limestone
17 DUNDEE FORMATION
Limestone
16 DETROIT RIVER GROUP
Limestone and dolomite
15 BOIS BLANC FORMATION a
Cherty limestone
LOWER DEVONIAN
14 ORISKANY FORMATION
Sandstone
SILURIAN
UPPER SILURIAN
13 BASS ISLANDS (BERTIE) FORMATION
Dolomite
12 SALINA FORMATION
Dolomite, shale, gypsum, salt
MIDDLE AND LOWER SILURIAN
11 GUELPH FORMATION
Dolomite
10 LOCKPORT - AMABEL FORMATIONS
Dolomite
9 CLINTON AND CATARACT GROUPS
Sandstone, shale, dolomite b
ORDOVICIAN
UPPER ORDOVICIAN
8 QUEENSTON FORMATION
Red shale
7 GEORGIAN BAY (CARLSBAD AND RUSSELL c) FORMATION
Grey shale with limestone interbeds, limestone upper member on Manitoulin Island
6 BLUE MOUNTAIN FORMATION
Grey and black shale
MIDDLE ORDOVICIAN
5 SIMCOE GROUP (OTTAWA GROUP c)
Limestone (5d, Lindsay Formation;
5c, Verulam Formation,
5b, Bobcaygeon Formation,
5a, Gull River Formation)
4 CHAZY GROUP
Limestone and shale
LOWER ORDOVICIAN
3 BEEKMANTOWN GROUP
Dolomite, sandstone
CAMBRO ORDOVICIAN
2 POTSDAM OR NEPEAN FORMATION
Sandstone
PRECAMBRIAN
1 Precambrian rocks
NOTES
a Includes Onondaga Formation in Niagara Peninsula
b Dolomite predominates on Manitoulin Island
c Formations in Ottawa area
SOURCES OF INFORMATION
Compilation by B.A. Liberty and D.F. Hewitt 1972, P.G. Telford 1976, 1984
Geology from maps of the Geological Survey of Canada and the Ontario Geological Survey
MANITOULIN I.
BRUCE PENINSULA
Georgian Bay
LAKE HURON
Collingwood
Midland
Lake Simcoe
QUEBEC
Ottawa
Ottawa R.
St Lawrence R.
U.S.A.
Kingston
Trenton
TORONTO
LAKE ONTARIO
Hamilton
Niagara Falls
Goderich
London
Grand River
Sarnia
Windsor
Lake St Clair
Thames River
Pelee Pt
LAKE ERIE
46°
45°
44°
42°
82°
77°
75°
MILES
0 25 50 75
0 40 80 120
KILOMETRES
ODM 4114 A

Figure 043.1 *Paleozoic geology of southern Ontario.*



LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

relatively small, ice-contact stratified drift and outwash deposits in the southwestern part of the township. The ice-contact deposits include kamelike features and a few small eskers which were deposited in association with the melting Georgian Bay lobe (Feenstra, in preparation). Extraction has been largely centred in outwash and ice-contact deposits where high-quality coarse aggregate has been used for a wide range of road-building and construction products. However, many of the sources are contaminated to a considerable extent by excessive fines, and careful sand control must be exercised during processing (Deike 1982).

Large parts of Euphrasia Township consist of bedrock outcrop or bedrock veneered by relatively thin drift. In the eastern part of the township, the Beaver Valley, which is a large re-entrant in the Niagara Escarpment, is underlain by Ordovician and Silurian shales of the Georgian Bay, Queenston, and Cabot Head Formations, and Silurian dolostones of the Manitoulin, Fossil Hill, Amabel, and Guelph Formations (Feenstra 1978, 1979; Liberty and Bolton 1971). The Amabel and Fossil Hill Formations form the resistant cap rock of the Niagara Escarpment. Interreefal areas of the Amabel Formation contain high quality dolostone suitable for use in crushed stone, concrete aggregate, building stone, and as raw material for lime manufacturing. Thin, drift-covered areas of the Guelph Formation also hold potential for future mining although this dolostone formation is best suited for the production of high purity dolomitic lime. Preliminary test results suggest that the Manitoulin Formation is suitable for light-traffic base and sub-base aggregates (B.H. Feenstra, Mineral Resources Geologist, Ontario Ministry of Natural Resources, Southwestern Region, personal communication, 1985).

NORTHUMBERLAND COUNTY

Hope, Hamilton, Alnwick, and Haldimand Townships, located in the western part of Northumberland County between Lake Ontario and Rice Lake, were also investigated during the 1986 field season. The predominant aggregate-bearing glacial deposits in the townships include ice-contact sands and gravels associated with the Oak Ridges Moraine, minor esker deposits, and glaciolacustrine beach deposits attributed to glacial Lake Iroquois.

The Oak Ridges Moraine was formed between two ice lobes, one advancing from the north and the other advancing from the east in the Lake Ontario basin (Gravenor 1957). The internal structure of the moraine is complex, having been influenced by several fluctuations in the position of the ice margins. The moraine consists of unpredictable volumes of stratified sand, gravel, and silt with minor amounts of incorporated till (Gravenor 1957). Although the moraine has been an important source of good-quality aggregate products for the townships for many years, the aggregate resources in many parts of the moraine are relatively unexploited. The predominance of sandy aggregate at the surface, and the presence of an overlying till layer, makes exploration for buried pockets or lenses of crushable gravel very difficult. In order to assess the aggregate potential of this extensive feature a small, portable drill rig was used to gather subsurface data. Further subsurface investigation would be necessary to delineate additional areas of crushable gravel suited for extractive development.

During the final stages of ice melting, postglacial Lake Iroquois occupied the Lake Ontario basin. The Lake Iroquois beach is very well developed south of the moraine in Hope and Hamilton Townships, and underlies most of Highway 401 in Haldimand Township. The beach deposits, generally consisting of well stratified, coarse sand and gravel, have been sources of good quality aggregate suitable for a wide range of road-building and construction needs for the Port Hope and Cobourg market areas. However, substantial parts of the deposits are unavailable for extraction because of the presence of cultural features such as highways, township roads, and both residential and other types of permanent development. In addition, a considerable volume of aggregate has already been removed from the beach deposits, and many pits are either currently depleted or nearing depletion.

The townships are underlain by the Ordovician Verulam and Lindsay Formations. The Verulam Formation is composed of fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The Lindsay Formation underlies the majority of the project area and is a fine-crystalline, rubbly, nodular-weathering limestone. Both formations are generally unsuitable for use in the production of crushed stone. Excessive drift covers most of the bedrock except for a few locations along the north shore of Lake Ontario, and mining of the underlying Ordovician formations has not taken place in the townships. However, the Lindsay Formation is mined for use in the manufacture of portland cement outside the project area by the St. Lawrence Cement Company at Colborne, and by the St. Mary's Cement Company at Bowmanville (Hewitt and Vos 1972).

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045. Aggregate Resources Inventory in Haliburton County

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

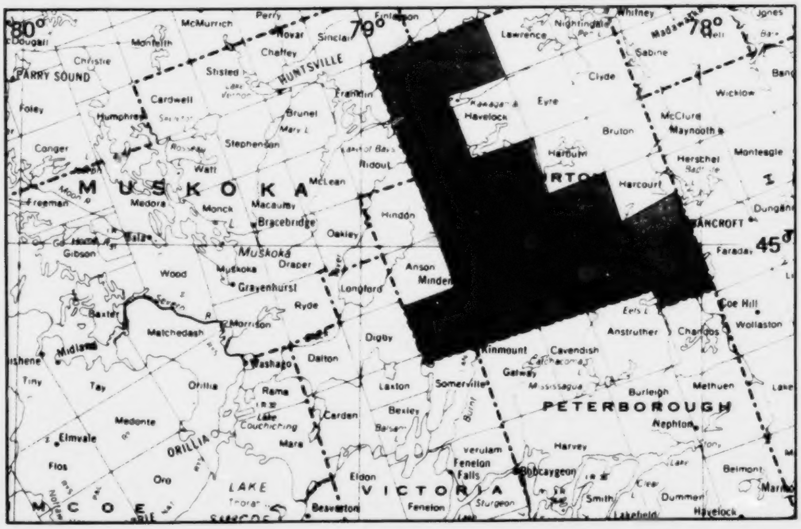
During the 1986 field season, aggregate assessments were undertaken in 13 geographic townships within Haliburton County. The townships assessed include: Livingstone, McClintock, Sherborne, Stanhope, Guilford, Minden, Dysart, Dudley, Lutterworth, Snowdon, Glamorgan, Monmouth, and Cardiff. The assessment work undertaken in parts of Sherborne and Stanhope Townships was in addition to work previously undertaken by the staff of the Leslie M. Frost Natural Resources Centre of the Ministry of Natural Resources. Population centres within the report area include the communities of Haliburton and Minden.

The purpose of this investigation was to delineate and determine the quality and quantity of aggregate within the area for both road-building and general construction uses. This information was required for the evaluation of development potential and land use decisions.

During the field investigation, all potential aggregate deposits, and both natural and man-made exposures, were examined in detail. Observations made at pit sites included the estimation of face height, percentage of gravel and sand, and the amount of objectionable materials present. Soil probing, hand augering, and geophysical techniques were used to assess subsurface materials in areas of limited exposure. A number of test holes were excavated using a backhoe, and aggregate samples were collected for quality testing.

BEDROCK

The bedrock in Haliburton County is part of the Grenville Province of the Canadian Shield. A complex array of Precambrian aged rocks underlies the report area and includes granitic, mafic intrusive, metasedimentary, and metavolcanic rocks. In places the bedrock is extremely weathered and friable, and unsuitable for aggregate use. In other areas, the bedrock is hard and resistant to weathering, and is considered a potential source of aggregate. Three quarries operate in the report area. In Guilford Township, dolomite is quarried for uses including construction aggregate, aquarium sand, poultry grit, and dolomitic lime. Road-building and construction aggregate is also extracted from a quarry south of the community of Haliburton, and quartz is mined in McClintock Township.


80°
79°
78°
45°
PARRY SOUND
HUNTSVILLE
M U S K O K A
PETERBOROUGH
V I C T O R I A
Bracebridge
Gravenhurst
Minden
Kinmount
Coe Hill
Maynooth
ORILLIA
Midland
Beaverton
Bobcaygeon
Fenelon Falls
Washago
Whitney
Lawrence
Nightingale
Sabine
Clyde
Eyre
Havelock
Harburn
Bruton
Harcourt
Anson
Hindon
Longford
Digby
Dalton
Laxton
Somerville
Galway
Cavendish
Anstruther
Chandos
Wollaston
Methuen
Burleigh
Harvey
Verulam
Fenelon
Eldon
Bexley
Carden
Mara
Rama
Orillia
Tay
Tiny
Medonte
Oro
Flos
Elmvale
Matchedash
Baxter
Wood
Gibson
Freeman
Medora
Monck
Macaulay
McLean
Oakley
Ridout
Draper
Muskoka
Ryde
Morrison
Stephenson
Brunel
Franklin
Stisted
Chaffey
Cardwell
Humphrey
Watt
Conger
Foley
Christie
Monteith
McMurrich
Perry
Sinclair
Finlayson
McClure
Wicklow
Monteagle
Herschel
Faraday
Dungannon
Belmont
Dummer
Smith
Lakefield
Havelock
Nephton
Jones
Lake Couchiching
LAKE

LOCATION MAP

Scale ; 1: 1 584 000 or 1 inch to 25 miles

SURFICIAL GEOLOGY

A discontinuous cover of till was deposited throughout the project area by glacial ice which advanced in a southwesterly direction (Henderson 1972, 1973; Finamore and Courtney 1982; Ford and Geddes 1986). This sandy till generally exists as a thin veneer over bedrock, although in several areas, significant thicknesses can be observed. These thicker till accumulations often flank bedrock knobs. Till is usually not well suited for aggregate use as it often contains excess fines and abundant oversize clasts. However, it may be a suitable source of fill in some localities.

The location of the remaining glacial sediments in the area is generally restricted to bedrock-controlled valleys. Such is the case with the glaciofluvial deposits in the area, which were deposited as the ice front melted back. Two types of glaciofluvial deposits are represented in the area: those closely associated with the ice during deposition are known as ice-contact deposits and include esker ridges; and outwash features, which were deposited by meltwaters flowing beyond the ice margin, represent the other type.

As the ice front retreated northward, lower lying areas were inundated by glacial lake waters. These areas include the Gull River Valley, as well as land near Kashagawigamog and Kawagama Lakes (Mollard 1980; Kaszycki 1985; Ford and Geddes 1986). Where meltwaters flowed into these water bodies, glaciolacustrine deltas or subaqueous fans were formed. Sand, silt and clay were deposited on the floor of these lakes.

AGGREGATE DISTRIBUTION AND QUALITY

The glaciofluvial outwash deposits are the major sources of aggregate in the study area. Major outwash features are situated in valleys presently occupied by the Kennisis, Redstone, Irondale, Little Drag, and Burnt Rivers. The outwash deposits consist predominantly of well stratified and uniformly bedded sand, although concentrations of crushable gravel may occur locally. For example, the outwash along the Irondale River consists largely of sand, but pits exposing fine to medium gravel have been opened in this outwash in southern Monmouth Township. The deposits in McClintock and Livingstone Townships also consist chiefly of gravel.

The ice-contact features in the report area, especially the eskers, represent important potential sources of crushable gravel. Significant esker systems are situated in northern Sherborne Township, western and southeastern Stanhope Township, southeastern Minden Township, and in northern Snowdon Township. The eskers often rise to between 20 and 60 feet (6 and 18 m) above the surrounding terrain, and consist largely of coarse gravel. The gravel contains abundant oversize clasts, consequently, a primary crusher would be beneficial for utilization. Ice-contact deposits, other than eskers, also contain locally significant resources of sand and gravel. These hummocky features are relatively abundant in McClintock, Livingstone, and Cardiff Townships, as well as near Drag Lake in Dysart Township.

Well stratified sand is the predominant material exposed in pits developed within the glaciolacustrine delta and subaqueous fan deposits. Pit-run aggregate is probably the most readily produced construction product from these features. Gravel is usually concentrated in pockets, and/or in the upper levels of the pits. With sand control and selective extraction these gravel accumulations may be suitable for crushing. The deltas and fans are situated in the Gull River valley and near Kashagawigamog Lake in central Dysart Township (Kaszycki 1985).

The sand and gravel in the report area appears to be suitable for most usual aggregate applications. The aggregate, however, contains highly weathered and friable rock which may restrict high-service-demand use, especially in concrete. In addition, the sands may contain abundant mica particles, which do not bond well in cement mixes. Many concrete bridge structures, observed during field investigations, were constructed using imported aggregate.

In general, the report area contains adequate resources of sand. Reserves of crushable gravel, however, are considered limited, especially in Sherborne, Dudley, Glamorgan and Lutterworth Townships; the exception being McClintock and Livingstone Townships, where existing deposits consist primarily of gravel and only limited quantities of sand are available.

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GEOPHYSICS/GEOCHEMISTRY PROGRAMS

046. Summary of Activities 1986, Geophysics/Geochemistry Section

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GEOPHYSICAL PROGRAM

During the 1986 field season, the Night Hawk geophysical test range near Timmins, Ontario, was utilized for testing, research, and instruction purposes by personnel from industry, universities, and government. Section staff carried out field work using the UTEM III electromagnetic system based on a standard (1 by 1 km) fixed source transmitter loop.

A project to investigate the potential for detecting and tracing conductive strata in Precambrian rocks overlain by thick Huronian stratigraphy in the Moose Lake sub-basin area west of Cobalt has been initiated (Hanneson and Huxter, Project 051). In this area, conductive horizons are largely contained within interflow sediments, which are in turn stratigraphically positioned within mafic volcanic rocks of Precambrian age. Techniques which would enable the tracing of these conductive horizons in the basement rocks beneath substantial thicknesses of Huronian sediments are of interest, both from a geological and an exploration viewpoint. Firstly, modeling of electromagnetic responses could reveal the depth of the Huronian sequence such that basement topography could be realized. Secondly, in some cases, there appears to be a spacial relationship between the interflow sediments and the contained conductive strata in basement rocks with cobalt-silver occurrences in the lower sequence of Huronian sediments above the unconformity. The study incorporates computer modeling of layered earth responses and plate-like targets, as well as the testing of field methods.

A gravity survey of the Lac des Iles area (1400 km^2) was carried out during the 1986 field season to aid in the regional geological interpretation of the mafic and ultramafic intrusive rocks in the area (Gupta *et al.*, Project 049). The largest intrusive complex in this area is located approximately 80 km northwest of Thunder Bay, and is host to significant palladium-platinum mineralization (Sutcliffe and Sweeney 1985; Macdonald 1985). Some detailed gravity profiles were established in order to map specific features of several intrusions in the area.

Two airborne electromagnetic-magnetic surveys covering areas of high mineral potential in the Oba-Kapuskasing region and the Pickle Lake, area were publically released on June 23 and October 14, 1986 respectively (Gupta and Barlow, Project 050; Gupta and Barlow, Project 047). The two surveys consisted of 28 036 line kilometres of data, which were acquired utilizing a flight line spacing of 200 m.

GEOCHEMISTRY PROGRAM

The third year of a reconnaissance till sampling project, which is being carried out in cooperation with the Engineering and Terrain Geology Section and forms part of the Black River-Matheson (BRIM) Program, will continue through the Winter, 1986-87. During the summer field season, unconsolidated cores obtained during two previous field seasons were sorted and filed in Drill Core Libraries at Kirkland Lake and Timmins. Surficial till exposures were hand sampled in areas inaccessible to either a backhoe or drilling equipment. Sampling by sonic drilling methods will continue through the winter months in areas not accessible by logging roads, so that an even distribution of sample sites in areas of thick drift can be realized (Steele and Baker, Project 080).

Geochemical research studies involving the development of remote sensing and lake water and sediment geochemical methodology in acid-stressed environments, were continued during the field season. At test sites located near Sudbury and the Montreal River (between Sault Ste. Marie and Wawa), a multidisciplinary team composed of scientists from three Ontario Ministries, two Ontario universities, and the Research Institute of Michigan, collected ground and airborne data which were synchronized with Landsat 5 overflights. A report containing the results of this project will be published in 1987 (Fortescue and Stahl, Project 052).

Orientation geochemical surveys were carried out in two areas of the province during the summer field season. A 400 km^2 area of lakes, including Opapimiskan and Skinner Lakes, was sampled using a gravity coring device, to establish the feasibility of regional geochemical surveying in the North Caribou Lake Belt. As well, within this area, two gold occurrences were selected for humus sampling to test the feasibility of obtaining reliable geochemical information on gold showings in this area (Fortescue and Webb, Project 077).

An orientation survey was carried out over the Roby Zone in the Lac des Iles intrusive complex using humus sampling techniques, in order to discover if humus could be used as a geochemical medium, in areas of relatively thin overburden, for platinum group metals. This site was chosen partially because of favorable forest cover conditions in the vicinity of significant palladium-platinum mineralization (Sutcliffe and Sweeny 1985; Macdonald 1985), (Fortescue and Webb, Project 048).

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047. An Airborne Electromagnetic-Magnetic Survey of the Pickle Lake Area, Districts of Kenora (Patricia Portion) and Thunder Bay

V.K. Gupta[1] **and R.B. Barlow**[2]

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[2]Section Chief, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

INTRODUCTION

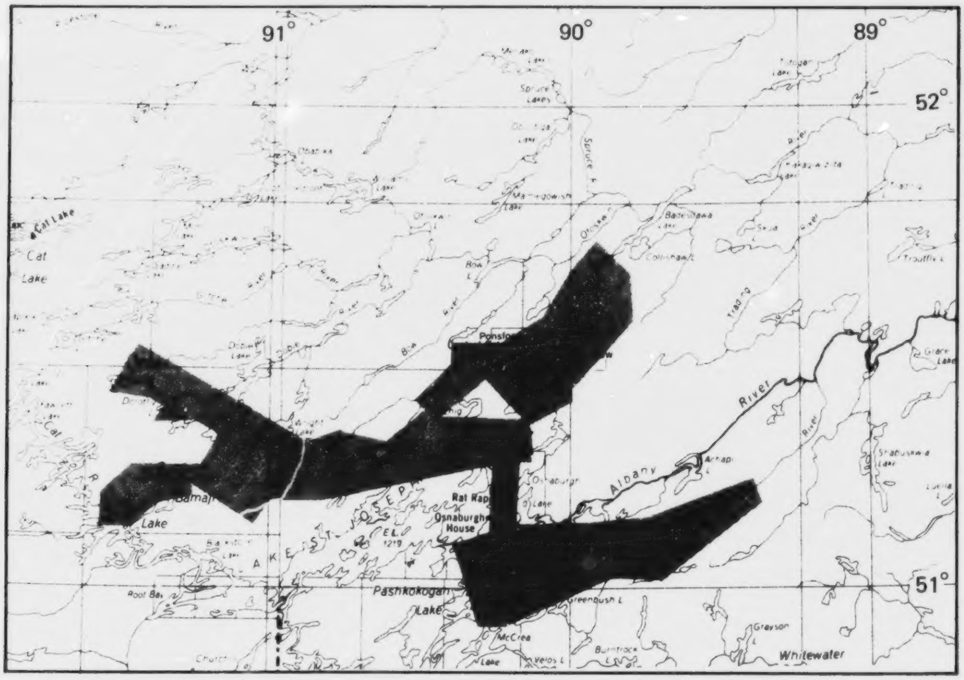
An airborne electromagnetic-magnetic survey was flown in the Pickle Lake area, during the period January 24 to February 26, 1986, by Geoterrex Limited on behalf of the Ontario Geological Survey. A total of 19 950 km of survey lines were flown at an average flight line spacing of 200 m and tie line spacing of about 3 km. The survey area was divided into six flying blocks (Figure 047.1), each having a different flight line direction, usually perpendicular to the regional geological strike. The electromagnetic conductors and magnetic anomalies mapped over the Pickle Lake and surrounding greenstone belts will aid in geological mapping and mineral exploration by providing important lithological and structural information. The results of the survey were released in the form of 59 maps, on October 14, 1986 (OGS 1986).

SURVEY INSTRUMENTATION

The survey aircraft was a CASA C212-200, twin turboprop short takeoff and landing (STOL) equipped with a 20 channel GEOTEM® time domain electromagnetic system comprised of a transmitter and loop, a digital receiver, and a sensor mounted in a towed bird. The primary electromagnetic pulses are created by a series of discontinuous sinusoidal current pulses fed into a three turn shielded transmitting loop surrounding the aircraft and fixed to the nose, tail, and wing tips. The transmitted primary field is discontinuous with each pulse lasting 1050 microseconds followed by 2280 microseconds of "off-time". Peak amperage through the loop is 600A, resulting in a primary magnetic dipole moment of 4.5 x 10^5 Am^2. The receiver is mounted horizontally in a bird, towed by the aircraft on a 135 m long cable. The GEOTEM digital receiver samples the secondary and primary electromagnetic field over 20 time gates, whose centres and widths are software selectable.

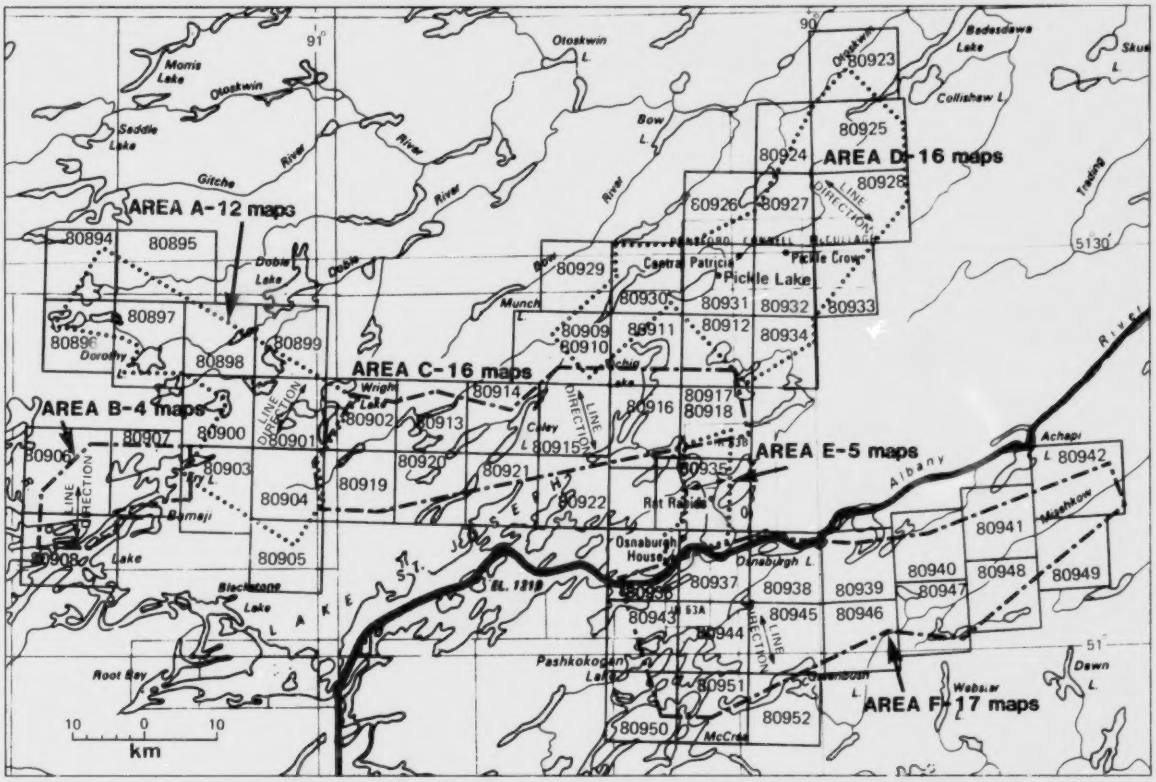
The digital receiver of the GEOTEM system has a sampling rate of 6 samples per second. Since there is no system time constant true, amplitude and anomaly shapes are recovered. Post-flight processing allows to optimize signal to noise ratio by limiting noise to about 20 ppm.

A Scintrex cesium vapor, single cell, split-beam magnetometer of 0.01 nt sensitivity at 1.0 second sample interval, was mounted in a stinger on the tail of the aircraft. A similar magnetometer was also set



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles


91°
90°
Morris Lake
Otoskwin
Saddle Lake
Gitche
River
Otoskwin L.
Bow L.
Badesdawa Lake
Skunk L.
Collishaw L.
AREA A-12 maps
AREA B-4 maps
AREA C-16 maps
AREA D-16 maps
AREA E-5 maps
AREA F-17 maps
LINE DIRECTION
80894
80895
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80951
80952
Dobie Lake
Munch L.
Central Patricia
Pickle Lake
Pickle Crow
Caley L.
Rat Rapids
Osnaburgh House
Osnaburgh L.
Pashkokogan Lake
McCrea
Blackstone Lake
Root Bay
Bamaji
Lake
ST. JOSEPH LAKE
Albany
River
Achapi L.
Miminiska
Webster
Dawn L.
5130
51°
EL. 1219
10 0 10
km

Figure 047.1 Airborne electromagnetic-magnetic survey, Pickle Lake area, showing the six blocks flown, their flight line directions, and map numbers

up at Pick Lake to monitor and record diurnal variation of the earth's magnetic field.

A MADACS digital acquisition system combining an Interdata 6/16 16 bit microprocessor and a Digidata 1640, 9 trac, 1600 bpi tape drive was on board the aircraft. A Decca 71 Doppler system, recording long track and cross track velocities and compass heading, was used to aid navigation. An RMS GR-33 heat sensitive graphic recorder was also used to display various data during the survey.

The aircraft was put through a series of pitches, yaws, and rolls to examine the noise induced in the magnetometer on-board resulting from aircraft manoeuvres (because of the eddy currents generated by the aircraft). This test is known as the Figure of Merit which shows how well the instrument is compensated for the eddy currents. For the Pickle Lake survey aircraft, the Figure of Merit was 3.33 nt and the average noise per manoeuvre was 0.28 nt.

MAPS

A photomosaic base was produced at a scale of 1:20 000 using Ontario Ministry of Natural Resources 1:15 840 scale aerial photographs.

The field EM data were subjected to a high frequency rejection filter to remove noise due to turbulence at the bird, and spike filtered to remove any atmospheric noise. The EM data was then run through an automated anomaly selection algorithm which identifies and flags anomalous responses based on amplitude criteria. The anomaly file was subsequently edited on a minicomputer with graphic capabilities. The edited file was then passed through a vertical plate model-fitting program to compute the corresponding conductivity thickness product. The rectangular vertical plate was chosen as best representing the majority of bedrock conductors in the Pickle Lake area.

Digitally recorded total field magnetic data was edited for extraneous values, and smoothed to remove noise by applying a 5 point triangular convolution, with an amplitude threshold of 0.75 nt. The data was then corrected for diurnal variations. The magnetic values from the lines and tie-lines were leveled together, in order to contour the magnetic data. The corrected profile data were gridded along a 2.5 mm grid (50 m true scale at the map scale of 1:20 000). A 3 point triangular convolution with a 5 nt threshold was also applied to the gridded values to smooth the magnetic contours. The aeromagnetic total field contours were then generated from the gridded data using a 10 nt interval.

ANOMALY SUMMARY

Using a GEOTEM Time Domain airborne electromagnetic system, some 16 500 EM anomaly intercepts were detected, as summarized in Table 047.1.

TABLE 047.1: ANOMALY SUMMARY OF THE PICKLE LAKE AREA.

Channel or Gate	Gate Centre (μs)	EM Intercepts(%)
1	300	6.2
2	400	10.1
3	500	12.1
4	620	7.4
5	740	4.8
6	860	3.6
7	1000	3.4
8	1140	3.8
9	1300	2.1
10	1460	4.0
11	1630	11.2
12	1820	31.3
		Total 100%

REFERENCE

Ontario Geological Survey

1986: Airborne Electromagnetic and Total Intensity Magnetic Survey, Pickle Lake Area, District of Kenora; by Geoterrex Limited, for Ontario Geological Survey, Maps 80 894 to 80 952, Geophysical/Geochemical Series, scale 1:20 000. Survey and compilation from February to July, 1986.

048. An Orientation Geochemical Study at the Lac des Iles Complex, District of Thunder Bay

John A.C. Fortescue[1] **and J.R. Webb**[2]

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[2]Geological Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

INTRODUCTION

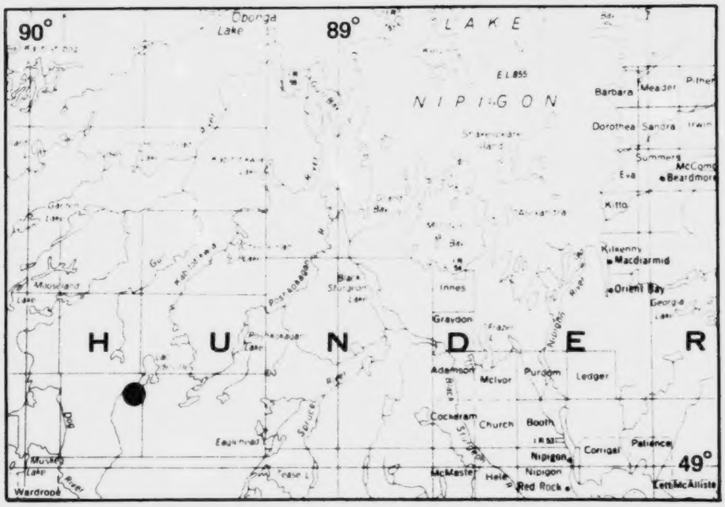
Studies have recently been completed which provide a standardized approach for the use of humus as a sampling medium for geochemical prospecting in areas of relatively thin overburden (Fortescue 1985; Fortescue and Webb 1986). These studies were completed in the vicinity of gold and base-metal deposits. In the Summer of 1986, a small scale test of the approach was completed in the vicinity of known platinum/palladium mineralization at the Lac des Iles complex, in order to discover if humus could be used as an indicator of platinum group metals.

The use of plants as indicators of platinum group metals (PGM) in favourable landscapes has been known for some time. For example Dunn (1986) reported enrichment of platinum and palladium in twigs and trunks of Black Spruce (*Picea mariana*) and Jack Pine (*Pinus banksiana*) as well as in stems of Labrador Tea (*Ledum groenlandicum*) obtained from sites in Saskatchewan where mineral deposits containing significant amounts of these elements are known to occur. Because humus is believed to accumulate elements between forest fires it is considered to be important to discover if it could be used as a medium for geochemical surveying for PGM in Ontario. The Lac des Iles site was considered as a good site for such an investigation to take place because the forest cover is well established in the vicinity of the areas known to be mineralized.

GEOLOGICAL SETTING OF THE SAMPLED AREA

This description of the geology of the Lac des Iles area is summarized from Sutcliffe and Sweeny (1985) which should be consulted for details of the complex geology of the area. Briefly, the Lac des Iles Complex consists of an ultramafic intrusion centred on Lac des Iles, and a gabbro intrusion to the south of the lake. These rocks were intruded into gneissic tonalitic granitoids. Locally, a younger series of granitic rocks intrudes the ultramafic and mafic rocks of the complex. The ultramafic intrusion is composed of two coalesing centres, each of which includes several intrusive phases. The centres are defined by the distribution of the lithologies and the attitudes of the layering. They are referred to as the Northern and Southern Centres.

The Southern Centre is elliptical in plan, with an irregular wehrlite core surrounded by websterite which, at several locations, includes inclusions of wehrlite. The gabbroic rocks within the Complex lie in an elliptical area situated to the south and west of the Southern Ultramafic centre. They are divided into an eastern and a western zone. The western zone includes several zones of pegmatitic gabbro, with grain sizes of up to 2 cm, which are mineralized. The eastern gabbro is weakly layered due to the development of magnetite-rich and pyroxene-rich layers, and locally has an igneous lamination. The platinum/palladium/sulphide mineralization occurs near the eastern gabbro/western gabbro interface (Sutcliffe and Sweeny 1985) and appears to be related to coarse-grained to pegmatitic gabbro, altered clinopyroxenite, and associated breccia zones



LOCATION MAP Scale : 1:1 584 000 or 1 inch to 25 miles.

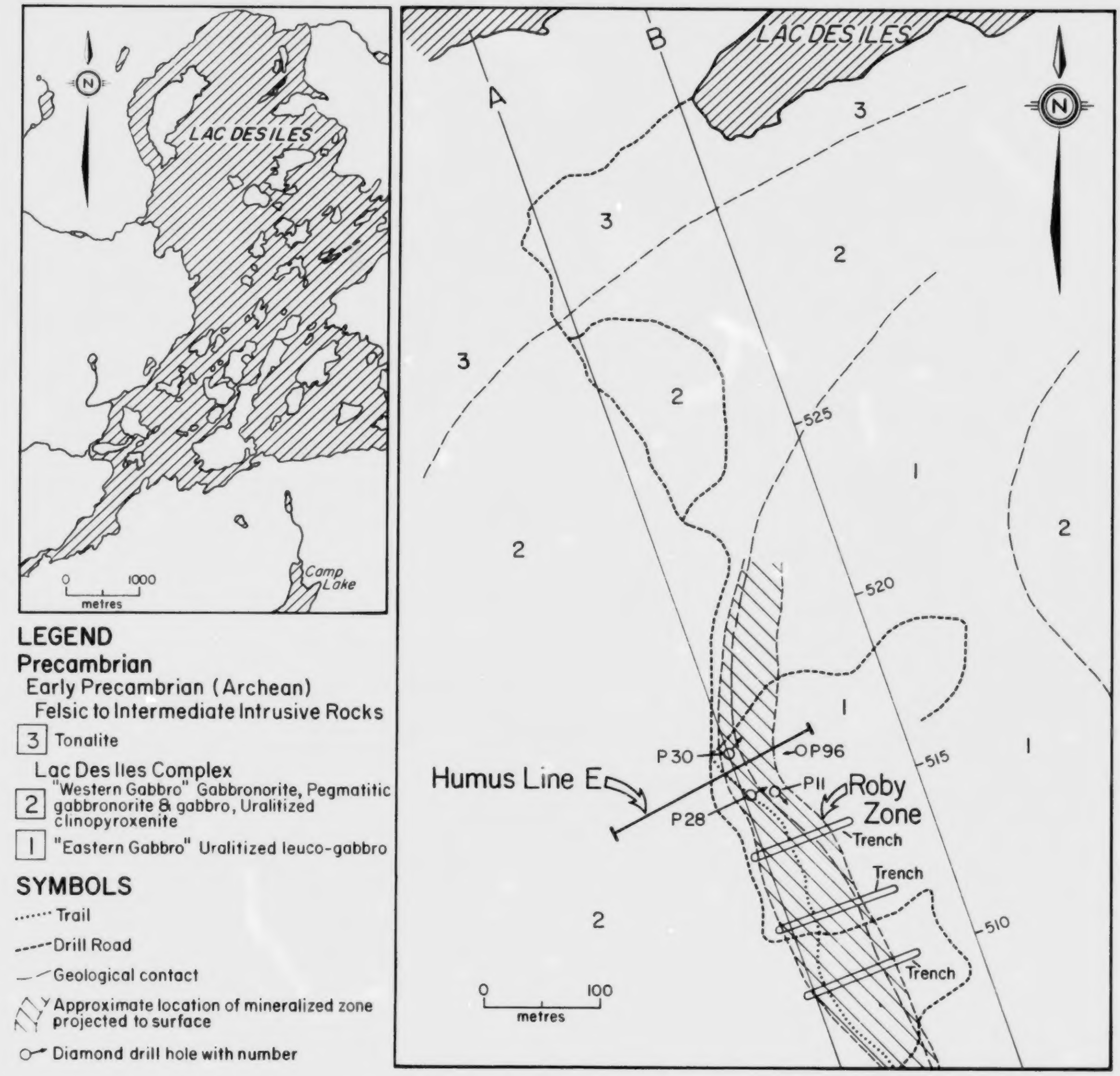

LAC DES ILES
0 1000 metres
Camp Lake
LEGEND
Precambrian
Early Precambrian (Archean)
Felsic to Intermediate Intrusive Rocks
3 Tonalite
Lac Des Iles Complex
2 "Western Gabbro" Gabbronorite, Pegmatitic gabbronorite & gabbro, Uralitized clinopyroxenite
1 "Eastern Gabbro" Uralitized leuco-gabbro
SYMBOLS
Trail
Drill Road
Geological contact
Approximate location of mineralized zone projected to surface
Diamond drill hole with number
A
B
525
520
515
510
Humus Line E
P30
P96
P11
P28
Roby Zone
Trench
Trench
Trench
0 100 metres

Figure 048.1. *Location Map and General Geology Map of part of the Lac des Iles Complex in the vicinity of Line E, from which the humus samples were collected. Lines A and B are reference lines for the Texasgulf Canada Limited and Boson Bay Mines Limited exploration grid (Sweeny and Sutcliffe, this volume).*

(Sutcliffe and Sweeny 1985; Macdonald 1985) as indicated in Figure 048.1.

Figure 048.1 also indicates the location of diamond-drill holes and outcrops of mineralized rock in the area. The line chosen for humus sampling is in the vicinity of the diamond-drill holes and surface mineral showings, and is positioned to cross the eastern/western gabbro contact.

METHODOLOGY

The samples of humus were collected at 10 m intervals along a traverse line, as described by Fortescue (1985). The difference in elevation between sample sites along the humus line was taken to provide section along which the soils and vegetation cover were described. The humus samples took the form of sods, which, after surface litter and mineral soil had been removed, were placed into multiwalled 22 kg (50 pound) paper sacs. The sacs were sealed and taken to Toronto where they were allowed to become air dry in a warm room prior to dispatch to a contractor for chemical analysis for PGM and other elements of interest. No chemical data had been obtained at the time this report was prepared.

SUMMARY

A small scale feasibility study involving the use of humus as a medium for geochemical prospecting in the search for platinum/palladium mineralization has been commenced. At the time of writing no results were available for discussion.

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049. Gravity Studies of Mafic and Ultramafic Intrusions in the Lac des Iles Area, District of Thunder Bay

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[2]Geophysical Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

INTRODUCTION

A gravity survey of the Lac des Iles area was conducted during the 1986 field season as part of an integrated Geophysical, Geochemical, and Precambrian study of the mafic-ultramafic intrusions (*see* Sutcliffe, and Fortescue and Webb, this volume).

Logistic support for the gravity program, in the field, was provided by the Precambrian Section, and included geological input by Richard Sutcliffe. The Lac des Iles area, in the Wabigoon Subprovince, is situated some 80 km northwest of Thunder Bay. The best known, and the largest intrusion in the area, is the Lac des Iles complex which consists of several intrusive phases ranging in composition from peridotite to gabbro, and is host to significant palladium-platinum mineralization (Sutcliffe and Sweeny 1985). The area is particularly suitable for gravity studies due to the presence of a large density contrast between the mafic-ultramafic intrusions and surrounding granitoid host rocks.

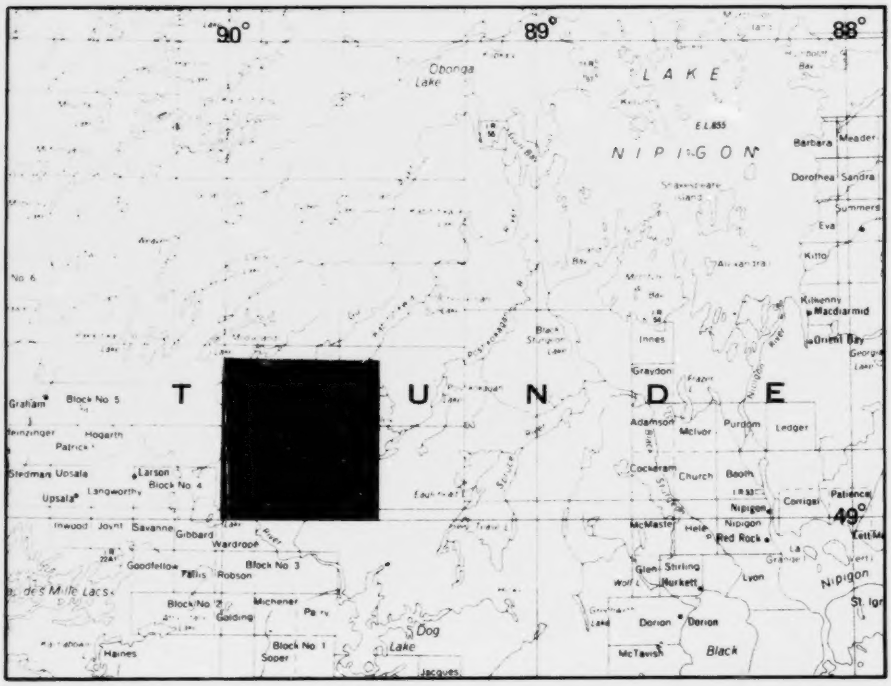
GRAVITY SURVEY

The survey area is bounded by Latitudes 49°00′ and 49°20′N and Longitudes 89°30′ and 90°00′W, covering an area of approximately 1400 km². Most of the area is accessible by numerous logging roads of the Great Lakes Pulp and Paper Company. Access to the remote areas was provided by a Jet Ranger helicopter on floats.

LOCATION AND ACCESS

During July and August, in a five-week period, over 700 gravity stations were established using Lacoste-Romberg gravimeters, numbers G294 and G626. On Lac des Iles the gravity station distribution is approximately one station per 0.5 km². Over other complexes (e.g. Tib Lake, Dog River, Taman Lake) the station distribution varies from one station per 0.5 km² to 1 km². Several detailed gravity profiles were established over some known intrusions with station spacings of 300 m or less. Two gravity profiles were also made at the Boston Bay Mine Limited Property; one across the Roby Zone at 15 to 30 m station spacing and the other along the east-west line established by Macdonald (1985), at 50 m intervals.

The gravity observations were tied to a local base station which was in turn tied to the control station at Thunder Bay airport, forming part of the National Gravity Network IGSN 1971, established by the Canada Department of Energy, Mines and Resources, Ottawa.


90°
89°
88°
Obonga Lake
LAKE
NIPIGON
T
U
N
D
E
49°
Graham
Block No 5
Block No 4
Block No 3
Block No 2
Block No 1
Upsala
Savanne
Gibbard
Wardrope
Dog Lake
Innes
Graydon
Adamson
McIvor
Purdom
Ledger
Cochram
Church
Booth
Nipigon
Red Rock
Corrigan
Patience
Dorion
McTavish
Black
Barbara
Meader
Dorothea
Sandra
Summers
Eva
Kitto
Kilkenny
Macdiarmid
Orient Bay
Haines
Soper
Jacques

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

Vertical control for most of the survey, including all detailed profiles, was provided by the GDD electronic "chain + level" from bench marks of the Ontario Ministry of Natural Resources. The elevation of Lac des Iles was established by precise leveling from a bench mark located about 1 km west of Lac des Iles. Gravity station elevations were then recorded as secondary elevations relative to the water level of Lac des Iles. Wallace and Tiernan altimeters, in pair, were also used to determine elevations for less accessible gravity station sites on lakes, bush roads, and swamps. Appropriate corrections for temperature and humidity variations were applied and elevation control, during altimeter work, was provided by occupying a point of known elevation at least once every one to two hours.

Locations of gravity stations were identified on 1:50 000 scale air photographs. The station positions were then transferred onto NTS maps and digitized with a precision of ±40 m.

Several hundred fresh rock samples were collected from outcrops at or near gravity station sites for density measurements which will be determined during the winter months in the laboratory.

The gravity data reduction is now underway for the purpose of compiling a Bouguer gravity map of the Lac des Iles area.

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050. An Airborne Electromagnetic—Magnetic Survey of the Oba—Kapuskasing Region, Districts of Algoma and Cochrane

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[2]Section Chief, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

INTRODUCTION

As part of a program to stimulate mineral exploration in high mineral potential areas of the province, an airborne electromagnetic-magnetic survey was flown in the Oba-Kapuskasing region, District of Cochrane. The survey area, located just southwest of Kapuskasing, was flown by Aerodat Limited from February 9 to March 11, 1986. The survey consists of 8086 line-km of data, in two areas, with line spacings of 200 m. In Pelletier-Ecclestone Townships Area (Maps 80 822 to 80 830, Ontario Geological Survey 1986a) 4836 km of data was collected, and to the south in Derry-Minnipuka Townships area (Maps 80 831 to 80 835, Ontario Geological Survey 1986b) 3250 km of data was collected (Figure 050.1). The results of the survey were released on June 23, 1986 (Ontario Geological Survey 1986a, b).

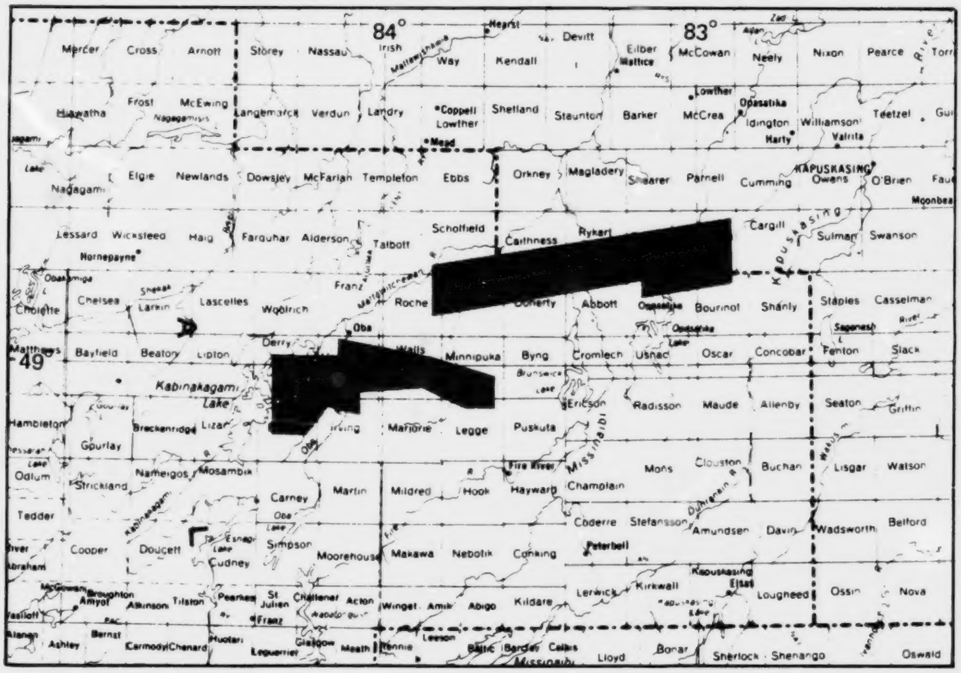
SURVEY INSTRUMENTATION

The survey aircraft was an Aerospatiale A-Star HR35 helicopter equipped with the Aerodat Electromagnetic System which measures inphase and quadrature components at three frequencies. Two vertical coaxial coil pairs were operated at 935 and 4600 Hz and a horizontal coplanar coil pair at 4175 Hz. The transmitter-receiver separation was 7 m. Inphase and quadrature components were measured simultaneously for three frequencies at 0.1 second sampling intervals employing a 0.1 second time constant.

A Geometrics G-803 proton precession magnetometer with a sensitivity of 1 nT, at 0.5 second sampling rate, was towed in a bird 15 m below the helicopter. An IFG proton precession magnetometer was operated at the base station to record diurnal variations of the earth's magnetic field.

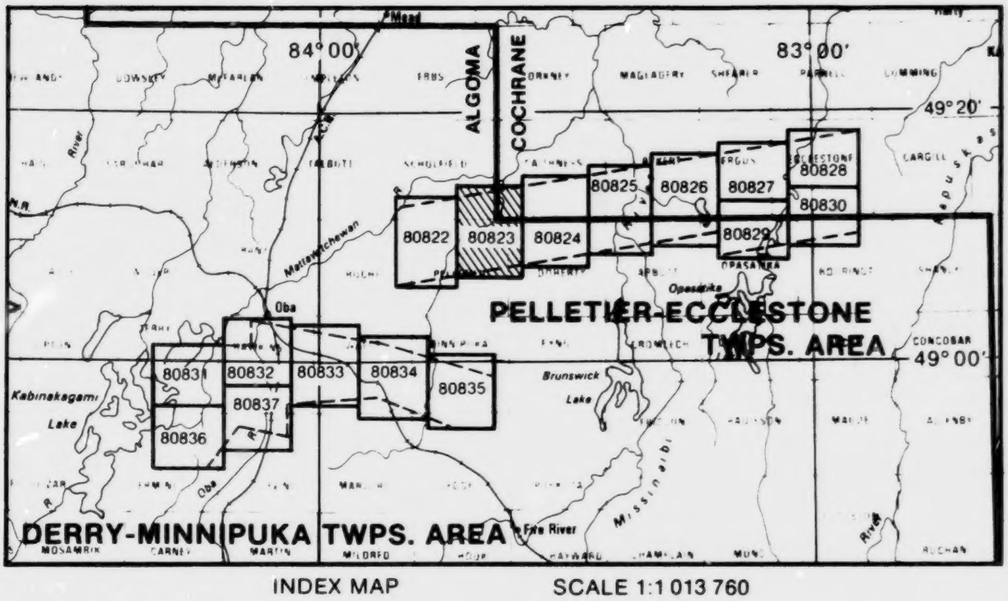
A Motorola Mini-Ranger MRS-111 radar navigation system was used for both navigation and flight path recovery. The helicopter position was derived several times per second to a relative accuracy of less than 10 m. Absolute positional accuracy of the survey data with respect to the photomosaic base maps should generally be within 25 m.

A Perle DAC/NAV digital acquisition system was used to record the 6 EM channels, the magnetometer, altimeter, and Mini-Ranger navigation data. An RMS dot-matrix recorder was used to display the data during the survey.


84°
83°
49°
Mercer
Cross
Arnott
Storey
Nassau
Irish
Way
Kendall
Devitt
Eilber
Mattice
McCowan
Neely
Nixon
Pearce
Hiawatha
Frost
McEwing
Nagagamisis
Langemarck
Verdun
Landry
Coppell
Lowther
Shetland
Staunton
Barker
McCrea
Lowther
Opasatika
Idington
Williamson
Teetzel
Hearst
Mead
Hanty
Val Rita
Elgie
Newlands
Dowsley
McFarlan
Templeton
Ebbs
Orkney
Magladery
Shearer
Parnell
Cumming
KAPUSKASING
Owens
O'Brien
Moonbeam
Nagagami
Lessard
Wicksteed
Haig
Farquhar
Alderson
Talbott
Scholfield
Caithness
Rykert
Cargill
Sulman
Swanson
Hornepayne
Obakamiga
Cheisea
Larkin
Lascelles
Woolrich
Franz
Roche
Dolerty
Abbott
Opasatika
Bourinot
Shanly
Staples
Casselman
Oba
Derry
Wallis
Minnipuka
Byng
Cromlech
Usnac
Oscar
Concobar
Fenton
Slack
Bayfield
Beatory
Lipton
Kabinakagami Lake
Brunswick Lake
Ericson
Radisson
Maude
Allenby
Seaton
Griffin
Hambleton
Gourlay
Breckenridge
Lizar
Irving
Marjorie
Legge
Puskuta
Odlum
Strickland
Nameigos
Mosambik
Carney
Martin
Mildred
Hook
Fire River
Hayward
Champlain
Mons
Clouston
Buchan
Lisgar
Watson
Tedder
Oba Lake
Coderre
Stefansson
Amundsen
Davin
Wadsworth
Belford
Cooper
Doucett
Cudney
Simpson
Moorehouse
Makawa
Nebotik
Conking
Peterbell
Abraham
Kapuskasing
Kirkwall
Lerwick
Ossin
Nova
Broughton
Amyot
Atkinson
Tilston
Pearkes
St Julien
Challener
Acton
Winget
Amik
Abigo
Kildare
Lougheed
Elsas
Franz
Ashley
Carmody
Chenard
Leguerrier
Glasgow
Meath
Rennie
Leeson
Baltic
Barclay
Collins
Missinaibi
Lloyd
Bonar
Sherlock
Shenango
Oswald

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles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83°00'
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PELLETIER-ECCLESTONE TWPS. AREA
DERRY-MINNIPUKA TWPS. AREA
Oba
Kabinakagami Lake
Brunswick Lake
Fire River
Missinaibi
INDEX MAP
SCALE 1:1 013 760

Figure 050.1. *Airborne electromagnetic-magnetic survey, Oba-Kapuskasing region, showing the map numbers.*

MAPS

A photomosaic base map for the survey area was prepared at a scale of 1:20 000 using Ontario Ministry of Natural Resources 1:15 840 scale aerial photographs which were controlled to 1:50 000 NTS maps.

The raw electromagnetic data were treated to a two stage digital filtering to reject major spherics and to reduce system noise. EM anomaly selection was based on a combination of automatic computer chosen criteria and manual editing. Discrimination of conductors was based upon the ratio of inphase to quadrature responses, variation of response with frequency, magnetic correlation, and variation of anomaly shape of the two coil configurations together with conductor pattern and topography. Conductance and depth estimates were determined, assuming a vertical half-plane model in free-space, at 935 Hz (signal-to-noise ratio permitting) where conductive overburden effects are minimal.

Digitally recorded aeromagnetic data were leveled and corrected for diurnal variations by subtraction of the digitally recorded base station magnetic data. The corrected profile data were interpolated onto a regular 0.25 cm (50 m true scale) grid, at the map scale of 1:20 000, using a cubic spline technique. The aeromagnetic total field contours at a 10 nT interval were then generated from the gridded data.

ANOMALY SUMMARY

Based on a vertical half-plane model in free-space, EM anomaly intercepts, as classified by Aerodat Limited, are summarized in Tables 050.1 and 050.2.

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1986a: Airborne Electromagnetic and Total Intensity Magnetic Survey, Oba-Kapuskasing Region, Pelletier-Ecclestone Townships Area, Districts of Algoma and Cochrane; by Aerodat Limited for the Ontario Geological Survey, Maps 80 822 to 80 830, Geophysical/Geochemical Series, scale 1:20 000. Survey and Compilation, February and March, 1986.
1986b: Airborne Electromagnetic and Total intensity Magnetic Survey, Oba-Kapuskasing Region, Derry-Minnipuka Townships Area, District of Algoma; by Aerodat Limited for the Ontario Geological Survey, Maps 80 831 to 80 837, Geophysical/Geochemical Series, scale 1:20 000. Survey and Compilation, February and March, 1986.

TABLE 050.1: ANOMALY SUMMARY: PELLETIER-ECCLESTONE TOWNSHIPS AREA (MAP NOS. 80822 TO 80830).

E.M. Anomaly	E.M. Anomaly Conductance (siemens)						
	>32	16-32	8-16	4-8	2-4	1-2	<1
Number of intercepts	76	105	186	283	287	280	2311
% intercept	2.2	3.0	5.3	8.0	8.1	7.9	65.5

Total E.M. Anomaly Intercepts = 3528
Low Frequency Inphase intercepts = 1426 or 40.4%
High Frequency Inphase intercepts = 1621 or 46.0%
High Frequency Quadrature intercepts = 481 or 13.6%

TABLE 050.2: ANOMALY SUMMARY: DERRY-MINNIPUKA TOWNSHIPS AREA (MAP NOS. 80831 TO 80837).

E.M. Anomaly	E.M. Anomaly Conductance (siemens)						
	>32	16-32	8-16	4-8	2-4	1-2	<1
Number of intercepts	3	13	23	41	42	46	775
% intercept	0.3	1.4	2.4	4.3	4.5	4.9	82.2

Total E.M. Anomaly Intercepts = 943
Low Frequency Inphase intercepts = 205 or 21.7%
High Frequency Inphase intercepts = 581 or 61.6%
High Frequency Quadrature intercepts = 157 or 16.7%

051. The Detection and Mapping of Basement Conductors Under Areas Covered by Thick Huronian Sedimentary Rocks, District of Timiskaming

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Geophysicists, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

An electromagnetic (EM) surveying project has been initiated in an attempt to trace conductive strata in Precambrian rocks overlain by a thick sedimentary cover. The project, which is still in the feasibility stage, has so far involved fairly extensive computer modeling, but only a modest amount of field testing. Conductive horizons are known to occur in interflow sediments west of Cobalt, Ontario, and one objective of the project is to apply EM methods in the Moose Lake area, for the purpose of tracing and modeling the geometry of such conductors. The general geology of the area is discussed by Johns (1985), and the Huronian stratigraphy overlying the basement is described by Legun (1984). Quantitative interpretation of the responses will give an indication of the strike of the volcanic rocks, as well as an inference of the thickness of the sedimentary cover. A second objective is to determine the reliability and the detectability of any conductivity contrast between the Precambrian basement and the overlying sedimentary rocks, and to determine if EM sounding techniques could be used to map the topography of the unconformity in this area.

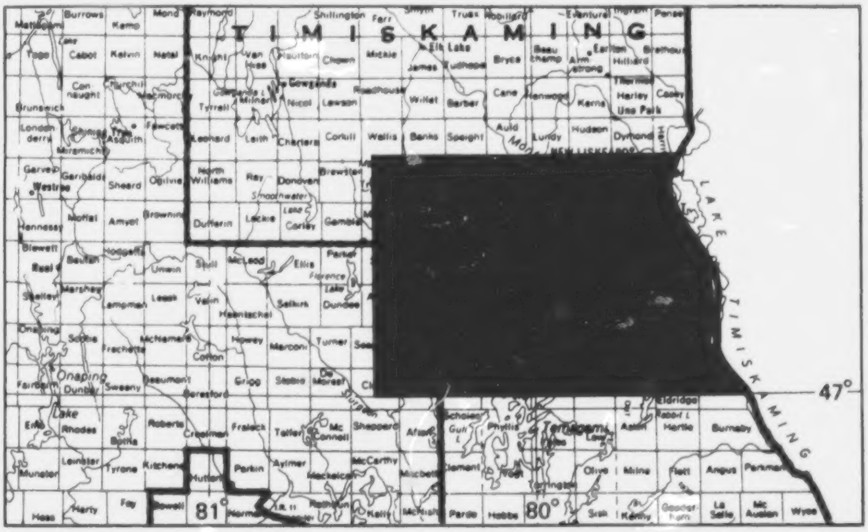
SURVEY EQUIPMENT

Because of a widely recognized capability for detecting deep conductors, the Lamontagne UTEM 3 Transient EM prospecting system was chosen for the measurements. This system, which is a wideband system (West *et al.* 1984), permits the detection of targets having a wide range of conductivities, and is also responsive to the conductivity variations in the host rocks. The latter capability is most important because host conductivity can be a leading factor in limiting deep detection of platelike conductors.

COMPUTER MODELS

PLATE IN A RESISTIVE HOST

With regard to the conductor-tracing objective stated above, the interpretation of wideband EM data is best performed when models are available which allow a nonzero conductivity for the host rock. This unfortunately leads to difficult numerical or experimental problems, and the assumption of zero host rock conductivity was made as a first approximation to the problem. Further testing of an algorithm, incorporating conductive host conditions, will eventually permit calculation of the responses of more representative models. The plate models presented here were computed by assuming the thin, rectangular conductive sheet to be in free space near a large, rectangular transmitter loop (the TURAM configuration). The program computes an approximate frequency-domain solution (using two-variable polynomials) of an integro-differential equation, formulated by Lamontagne and West (1971). The frequency domain response is subsequently transformed into the UTEM transient re-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Van Hise
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McIntyre
Elk Lake
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Tudhope
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Tyrrell
Leonard
Leith
Charters
Corkill
Wallis
Banks
Speight
Auld
Lundy
Hudson
Dymond
Londonderry
Asquith
Garvey
Gariboldi
Westree
Sheard
Ogilvie
North Williams
Ray
Donovan
Brewster
Smoothwater
Hennessy
Moffat
Amyot
Browning
Dufferin
Lackie
Corley
Gamble
Blewett
Beulah
Hodgetts
Umwin
Scholes
McLeod
Ellis
Parkin
Selkirk
Dundee
Florence
Marshay
Lampman
Leask
Valin
Hamischel
Turner
Onaping
Scadding
Frechette
McNamara
Cotton
Hobbs
Mercon
Dunbar
Sweeny
Beaumont
Grigg
Beresford
Rhodes
Roberts
Creelman
Fraleck
Tofler
McConnell
Shepperd
Afton
Phyllis
Temagami
Aston
Hartle
Burnaby
Leinster
Tyrone
Kitchener
Mutton
Parkin
Aylmer
McCarthy
Mackelcan
Milne
Olive
Flett
Angus
Parkman
Hess
Harty
Fay
Powell
Norman
Kelly
McNish
Pardo
Strathy
Goodall
La Salle
McAuslan
Wyse
Eldridge

LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

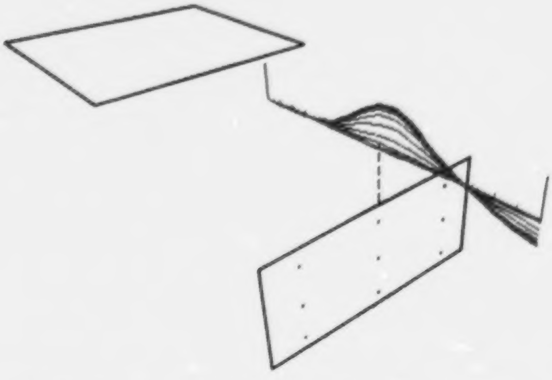

Figure 051.1. Perspective view of survey for a vertical 1000 x 500 m plate setup at 250 m depth. The loop sizes average 1.0 x 1.0 km and the plate is 1 km (horizontally) from the front of the loop.

sponse using program YVESFT (Holladay 1981). The program can simulate ten channels of UTEM data over a seventeen-station traverse in about ten minutes, using a DEC Professional 350 microcomputer.

A perspective view of a simulated survey setup is shown, with UTEM profiles, in Figure 051.1, for a vertical plate at 250 m depth. Profiles of simulated UTEM responses over plates, having a range of dips and depths, have been prepared and are presented in Figure 051.2 (vertical component, Hz) and Figure 051.3 (horizontal component, Hx, in the direction of the traverse). The responses show the effect of varying depth and dip for a 1000 by 500 m plate, whose top edge is 1000 m (horizontally) from the loop. For a given dip, the effect of increasing plate depth can be understood by proceeding down a given column of profiles in either Figure 051.2 or Figure 051.3. The profile amplitudes decrease with depth (note expanding scales), and the peaks become more rounded. For a given depth, the effect of changing dip can be understood by proceeding across a given row of profiles in either Figure 051.2 or Figure 051.3, and these changes are mainly the effect of changes in primary field coupling. In fact, even the sign of the anomaly changes between dips of 150 and 120 degrees, for the two shallower plates.

Responses in Figures 051.2 and 051.3 are for a plate having a conductance of 20 siemens, and UTEM channel 4, of the transient decay, is signified by an arrow. Later channels (lower channel number) have weaker amplitudes. Because of certain design features of the UTEM system (West *et al.* 1984), time scaling can be applied to the computed responses. This means that the profiles in Figures 051.2 and 051.3 could be for 10 siemen plates, with channel 5 signified by the arrow, or they could be for 40 siemen plates, with channel 3 signified by the arrow. Each time the conductance is doubled (or halved) the channel number decreases (or increases) by one.

HOST RESPONSE

The UTEM 3 data will always exhibit a background response governed by the conductivity structure of the earth. Computed host responses are the responses of simple earth models, which can be used to infer (in the absence of platelike responders) the conductivity structure of the host rock, and the profiles, as discussed below, were computed using a program written by Polzer (1985). Figure 051.4 is the response of a homogeneous half-space, and the arrow signifies channel 4 when the host resistivity is 1000 ohm-m.

Figure 051.5 illustrates the response of a 1000 ohm-m half-space overlain by layers of various resistivities and thicknesses. Again the arrow indicates channel 4. A given row of profiles in Figure 051.5 shows the effect of changing the resistivity contrast for a given layer thickness, while a given column of profiles, in the same figure, demonstrates the effect of increasing the layer thickness for a given conductivity contrast.

COMBINED RESPONSES

Using the above models for a plate in free space and for a layered earth, it is possible to estimate the response of a plate in a conductive earth, but only for late times, through superposition. Conversely, stripping observed responses of their host effects is a common practice in interpreting platelike responses in any non-free-space environment. The attempts made below to estimate the system's depth limits are based on the superposition of late time response.

SURVEY DESIGN CONSIDERATIONS

The object of some surveys is to discover conductive regions, within the ground, with as much sensitivity as possible. Survey design (based in part on MacNae 1985) must consider, firstly, the question of target signal level to system noise level, and then, secondly, the target signal level to geological noise. Basically, the Loop-Target geometry, and the transmitter moment and waveform, control the system's theoretical signal-to-noise ratio. Both geometry and moment must generally be optimized for deep penetration.

TARGET SIGNAL LEVEL AND DEPTH LIMITATIONS

If a conductor has three dimensions (L x M x S) and the middle, or average, dimension is M, then the maximum anomaly (the inductive limit) at a depth of 0.5 M is 50 percent, and the typical anomaly size is 30 percent (Macnae 1985). Table 051.1 shows the maximum and typical responses for a conductor at various depths.

A stacking time of one minute, in average field conditions, allows for <1 percent noise for a region outside the transmitter Loop (during moderately high spherics), compared to <0.2 percent during good conditions (low spherics) for the UTEM 3 system.

Based on Table 051.1, and speculating on an average thin conductor size of 1000 by 500 m (general results from assessment file search), the case where the typical anomaly is as large, or larger,

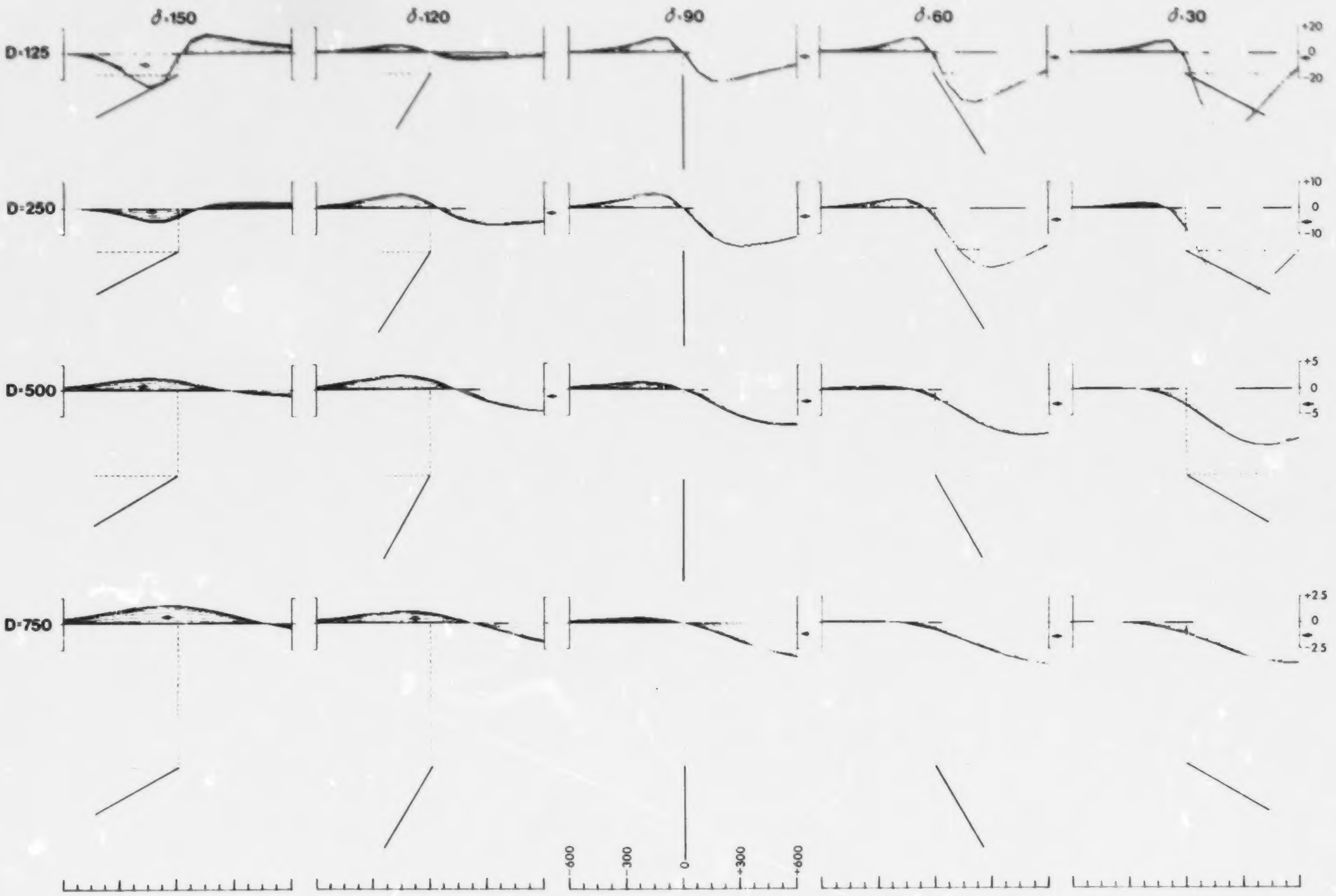

Figure 051.2. Computed vertical component UTEM responses of suite of platelike targets with changing dips and depths to surface. Responses for depths of 125 m, 250 m, 500 m, and 750 m are illustrated with corresponding dips of 30, 60, 90, 120 and 150 degrees. The arrow indicates the channel 4 response of a 20 siemen plate whose top is 1000 m horizontally from the loop.

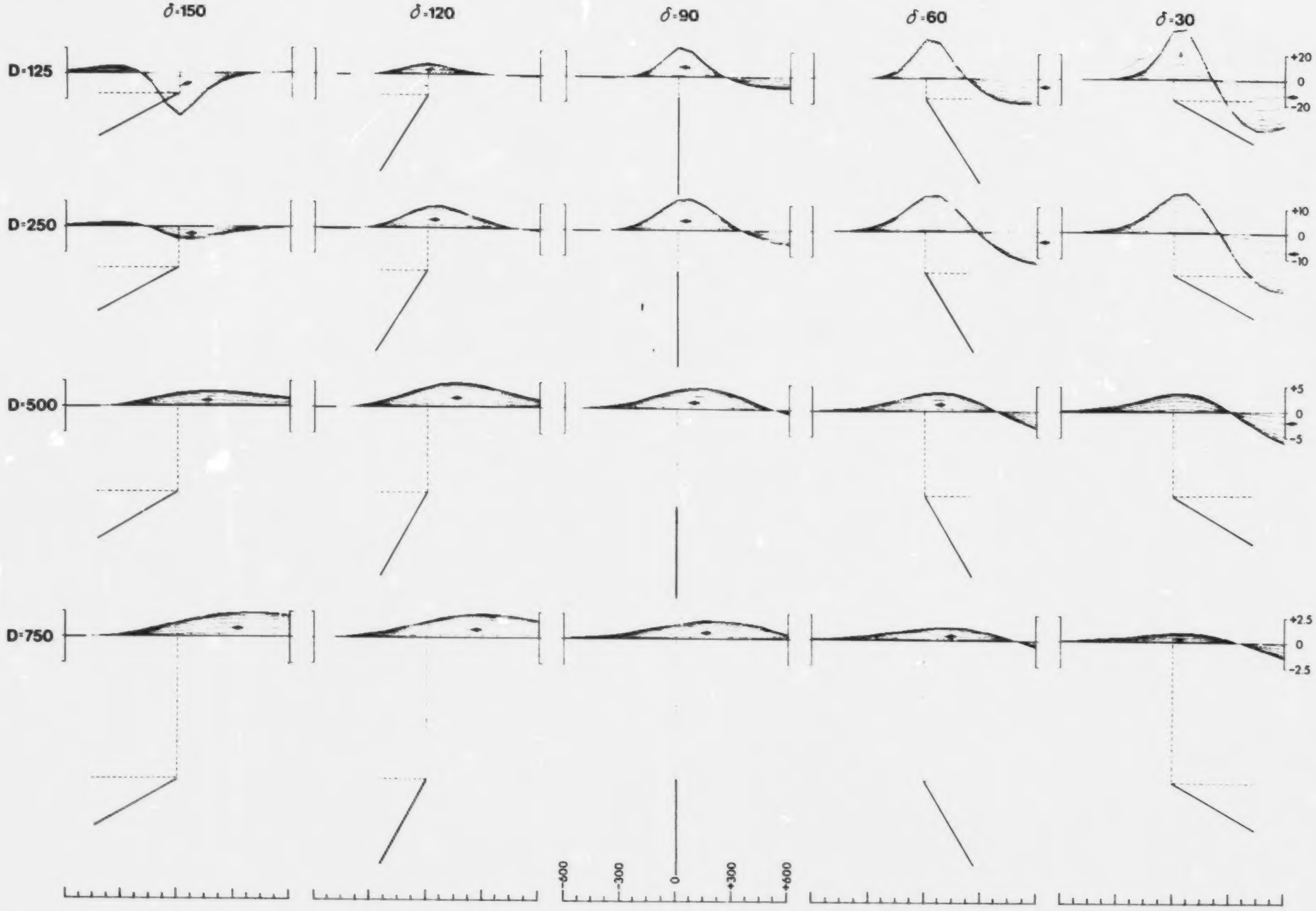

Figure 051.3. *Computed horizontal component UTEM responses for the same suite of models as in Figure 051.2. The horizontal component presented is the component parallel to the survey profile.*

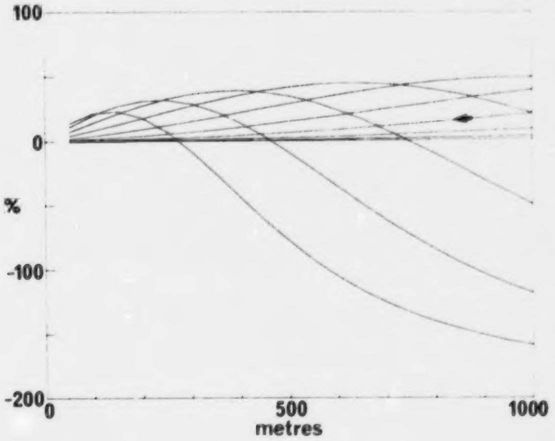

Figure 051.4. Computed vertical component UTEM response for a 1000 (ohm- m) half-space. The transmitter is located to the left of the profile and is 1.0 by 1.0 km. The arrow indicates the UTEM channel 4 response.

than the noise, places the depth limitation of the system at about 2 M or 1000 m. This limitation would apply to the case of a saturated conductor in free space, and may be better, or worse, in the presence of a conductive host (Lajoie and West 1976). Preliminary results in the survey area suggest a low conductivity layer (representing resistive Huronian rocks) above the basement, thus the layered-earth masking would not seriously effect late time responses. For this particular case, assuming large conductors below a resistive layer and best noise conditions, the estimated depth limitation for confident interpretations appears to be somewhat less than 1000 m for a single, platelike conductor. Near surface geological features will greatly affect the early time responses, thus any confident interpretation of conductors will be based on late time responses.

ORIENTATION SURVEY

Figure 051.6 illustrates the locations of two survey lines, with the transmitter loops used for each. The line locations are in areas where the sedimentary rocks were thought to be thick, on the assumption that detecting a conductor on either line would justify a major survey within the Moose Lake sub-basin.

The data from loops 1 and 2 (Figures 051.7(A) and 051.7(B), respectively) are displayed in the standard UTEM format. Each loop was used to collect one line of data, and for each line, two components of the secondary transient magnetic field were measured, using a system base frequency of 30 Hz. A preliminary layered earth model (Figure 051.7(C)) is also presented for comparison.

The data displays channel 1 on the lower axis, channels 2 to 5 on the middle axis, and channels 5 to 9 on the upper axis. The data is continuously normalized (to the primary field) and channel 1 reduced as described by West *et al.* (1984). The data from the two loops show similar behaviour on channels 2 to 6 (late time responses), and different behaviour on channels 7 to 9 (early time responses).

Three types of responses could be interpreted from this field test: responses from platelike conductors, responses from layered-earth structure, and responses from near-surface overburden features.

CONCLUSIONS

There are no obvious responses from platelike conductors apparent in the field data, but a subtle response may occur at 550 S on loop 1 on the Hz data.

A preliminary model was created, using a layered-earth program, to fit the data from loop 2. The fit with loop 1 data is also reasonable at late times suggesting similar deep-conductivity layering in both areas. Figure 051.7(C) shows the computed response of the best model found so far, for the measured data. Although ambiguity exists when suggesting that the 1000 m thick middle layer represents the Huronian stratigraphic column, there appears to be sufficient conductivity contrast to warrant future field work and modeling of the respective responses.

FUTURE ACTIVITIES

The project will continue at the feasibility stage, with additional test lines planned over Sharp Lake, as well as further west, near the basement exposure at McLaren Lake. The data will be carefully examined for basement conductors and for indications of a significant resistivity contrast, between Huronian sedimentary rocks and the basement. A formal ground survey on cut lines is anticipated, however, further testing is required prior to selection of the grid area. An existing computer program, which gives the EM response of a plate in a conductive host (Hanneson and West 1984) is being modified for the large stationary loop configuration and will be used for more realistic simulations and more accurate interpretation of wideband EM responses.

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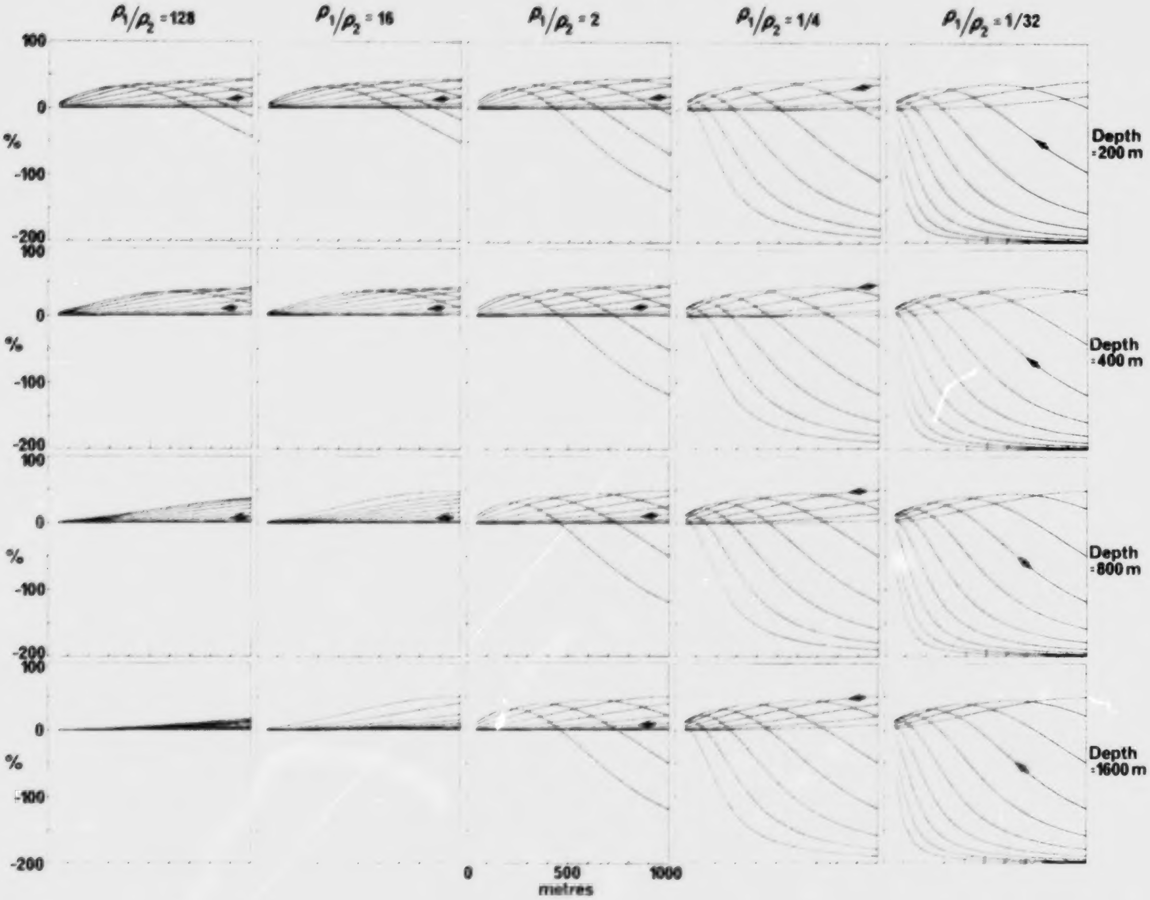
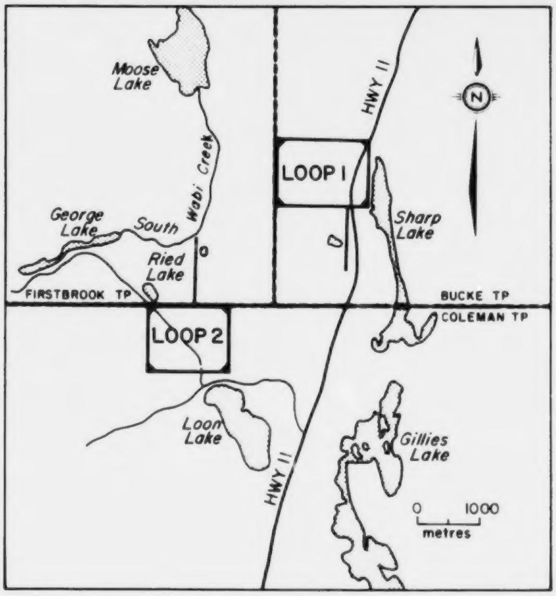


Figure 051.5. Computed UTEM responses of a two-layer earth with changing thickness and resistivity of the upper layer. All the channels are plotted on the same axis with channel 4 indicated by an arrow. The models were calculated for thicknesses of 200 m, 400 m, 800 m, and 1600 m for the first layer of variable resistivity overlying a 1000 ohm- m half-space. The transmitter was a 1.0 by 1.0 km loop located to the left of the profiles.

TABLE 051.1: ESTIMATED ANOMALY SIZES FOR INDUCTIVELY SATURATED PLATES AND FOR TYPICAL PLATES OF VARIOUS DEPTHS.

Depth	Maximum Anomaly	Typical Anomaly
0.5*M	50%	30%
1*M	25%	10%
2*M	7%	2.5%
3*M	3%	1%


Moose Lake
HWY 11
N
Wabi Creek
LOOP 1
Sharp Lake
George Lake
South
Ried Lake
FIRSTBROOK TP
BUCKE TP
COLEMAN TP
LOOP 2
Loon Lake
Gillies Lake
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0
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Figure 051.6. Plan view showing the loops locations in the general area west of Cobalt.

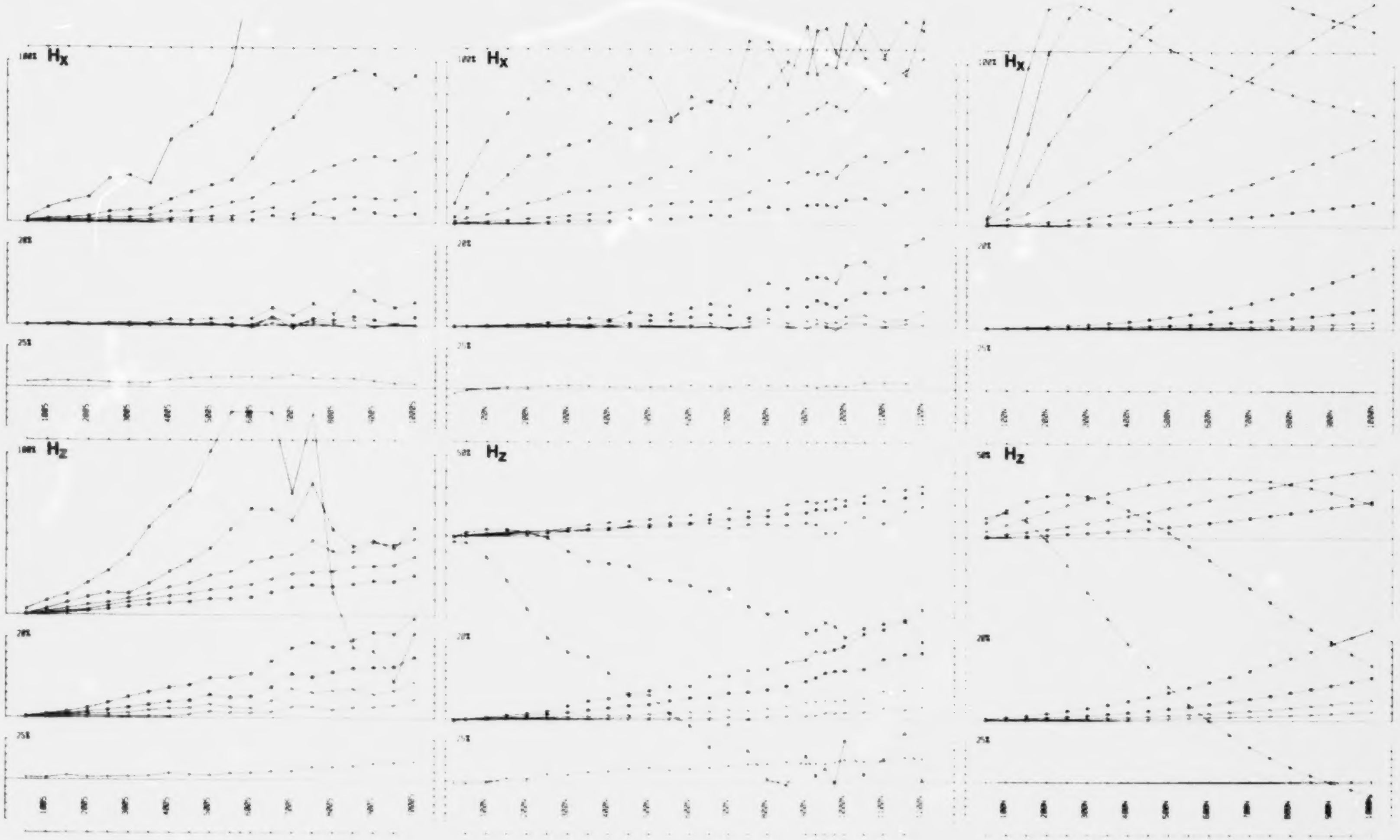

Figure 051.7. (A) Loop 1 UTEM horizontal and vertical component field data. (B) Loop 2 UTEM horizontal and vertical component field data. (C) Computed three-layered earth model for horizontal and vertical components. The model has a first layer thickness of 26 m with a 100 ohm- m resistivity, a second layer thickness of 1000 m with a resistivity of 20 000 ohm- m and a half-space resistivity of 1000 ohm- m. The transmitter loop used was 1.0 by 1.0 km.

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052. The Northern Lakes Interdisciplinary Study, Districts of Sudbury and Algoma

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[2]Geological Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

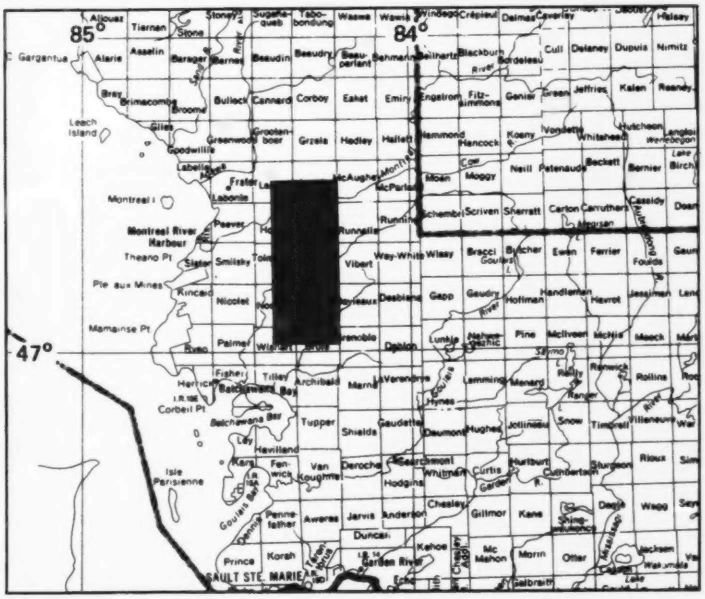
INTRODUCTION

Since 1980, a series of annual, interdisciplinary studies of northern lakes have been completed which were designed to improve the effectiveness of regional geochemical survey methods for mineral resource appraisal, and to provide information on those areas where the science and technology of geochemistry have a direct bearing on the processes of lake acidification. These investigations were completed near Wawa (Fortescue *et al.* 1981, Fortescue 1984, Fortescue *et al.* 1984); south of the Montreal River (Fortescue and Diamond 1984); and near Sudbury (Fortescue 1985, 1986). The project described here is the climax of the series, and was carried out on a large scale with the involvement of four organizations, in addition to the Ontario Geological Survey.

This year's project draws on experience obtained by interdisciplinary teams during past years. Briefly, prior to 1984, the team was largely concerned with the geochemical stratigraphy of acid lakes, and the development of a reliable diatom-inferred pH methodology designed to describe the pH history of lakes during the past 100 years. The latter was developed by Mike Dickman, Department of Biological Sciences, Brock University, St. Catharines, who has been a member of the team for several years. By 1984 we were satisfied that the pH history of a northern lake could be reliably described, using diatom-inferred pH measurements, and that the methodology was clearly too labour intensive for use on every core collected during a regional geochemical survey designed for mineral resource appraisal.

Consequently, in 1984, a small scale geochemical/limnological/remote sensing project was completed in Raaflaub Township, District of Algoma (Fortescue and Diamond 1984), designed to investigate the possibility of using remote sensing to identify lakes sensitive to the effects of acid precipitation. The results of this study were encouraging (Fortescue and Singhroy 1985, 1986), and indicated that clear, acid lakes might be identified on the basis of remotely sensed and limnological properties, although the identification of such lakes from Landsat data was not proven. Unfortunately these results could not be reproduced on the same lakes a year later (Fortescue and Webb 1985), and it was clear that a more comprehensive study was required to carry the investigation to a conclusion.

In May 1986, scientists, interested in relationships between geochemistry/limnology and remote sensing of northern lakes, met for an informal workshop (which was co-ordinated by the senior author) at the Ontario Centre for Remote Sensing, Toronto. It was soon agreed that a comprehensive database, contributed to by team members working on the same set of lakes at the same time, was likely to produce effective answers to the general problem of remote sensing and stressed lakes. The meeting planned an interdisciplinary field study which would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Caverley
Halsey
C Gargantua
Alarie
Asselin
Barager
Barnes
Beaudin
Beaudry
Beau-parlant
Rehmann
Bellnertz
Blackburn
Bordeleau
River
Cull
Delaney
Dupuis
Nimitz
Bray
Brimacombe
Broome
Bulleck
Cannard
Corboy
Eahet
Emiry
Engstrom
Fitz-simmons
Genier
Green
Jeffries
Kalen
Reaney
Leach Island
Giles
Goodwillie
Greenwood
Grootenboer
Grzela
Hadley
Hallett
Hammond
Hancock
Koany
Vondette
Whitehead
Hutcheon
Langlois
Wenebegon
Labelle
Fraser
Labonte
McAughey
Montreal
McParland
Moan
Moggy
Cow
Neill
Petenaude
Beckett
Bernier
Lake Birch
Montreal I
Peever
Montreal River Harbour
Runnalls
Schembri
Scriven
Sherratt
Carton
Carruthers
Cassidy
Theano Pt
Sister
Smilsky
Vibert
Way-White
Wisay
Bracci
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Butcher
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Foulds
Pte aux Mines
Kincaid
Nicolet
Desbiens
Gapp
Gaudry
River
Hoffman
Handleman
Havrot
Jessiman
Mamainse Pt
Ryan
Palmer
Grenoble
Dablon
Lunkie
Nahwegezhic
Pine
McIlveen
McNie
Meech
Fisher
Herrick
Tilley
Archibald
Marne
LaVerendrye
Lamming
Menard
Reilly
Ranger
Renwick
Rollins
Batchawana Bay
I.R. 15E
Corbeil Pt
Batchawana Bay
Tupper
Shields
Goulais
Hynes
Gaudette
Deumont
Hughes
Jollineau
Snow
Timbrell
Villeneuve
River
Lay
Havilland
Isle Parisienne
Kars
I.R. 15A
Fenwick
Van Koughnet
Deroche
Searchmont
Whitman
Hodgins
Curtis
Garden
Hurlburt
Cuthbertson
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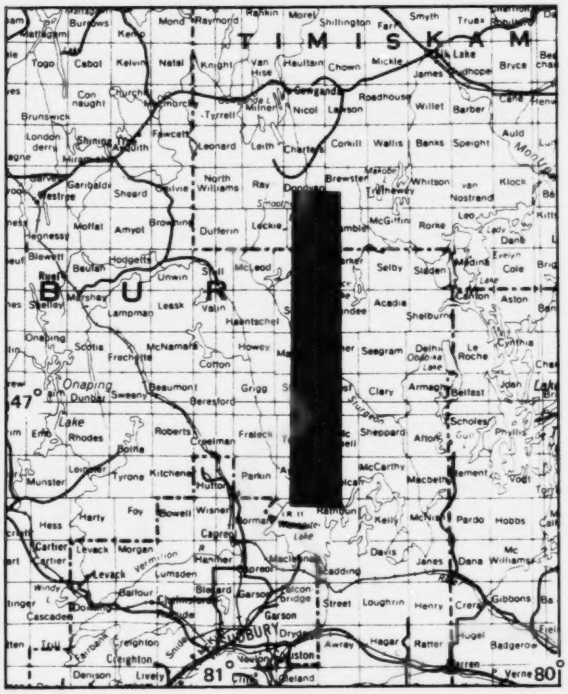
Sturgeon
Rioux
Goulais Bay
Pennefather
Awerea
Jarvis
Anderson
Chesley
Gillmor
Kane
Shingwauk
Deagle
Wagg
Dennis
Duncan
Prince
Korah
Tarentorus
I.R. 14
Garden River
Kehoe
Chesley Add.
Mc Mahon
Morin
Otter
Mississagi
Jackson
Wakomata Lake
SAULT STE. MARIE
Echo
Galbraith

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles



LOCATION MAP

Scale: 1:1 584 000
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take place in August 1986 at two test sites; one near Sudbury, where the Ontario Ministry of the Environment has a multiyear, multidisciplinary database for a large number of lakes; the other in the area south of the Montreal River, District of Algoma, where the Ontario Geological Survey had previously found a number of lakes with a pH lower than 5.0. The interdisciplinary team was to include contributions from the Ontario Geological Survey, the Ontario Ministry of the Environment, Laurentian University, Brock University, the Research Institute of Michigan, and the Ontario Ministry of Natural Resources (Ontario Centre for Remote Sensing).

THE INTERDISCIPLINARY FIELD PROJECT

The interdisciplinary field project, which was planned in May, was carried out during a 15 day period in mid-August 1986. Briefly, the senior author was responsible for the Ontario Geological Survey component of the project (as described below); Roger Pitblado (Professor, Laurentian University, Sudbury) was responsible for the organization of the field program. and coordination of a laboratory for subsampling waters for the Ontario Ministry of the Environment; Mike Dickman (Professor, Brock University, St. Catharines) was responsible for detailed diatom-inferred pH measurements on special lake sediment cores obtained from a small number of selected lakes; Fred Tanis (Environmental Research Institute of Michigan) was responsible for collecting spectral reflectance data from a helicopter, from lakes of special interest, on days when conditions were suitable for an overflight by the Landsat 5 satellite, and for the collection of several kinds of very detailed optical measurements of lake waters, from a small number of lakes, using a canoe; and V.H. Singhroy (Canada Centre for Remote Sensing, Toronto) was responsible for arranging flights over the study areas, by an aircraft from the Canada Centre for Remote Sensing (Ottawa), for the purpose of collecting surface reflectance data from a MEIS II remote sensor. The subsamples of water, obtained from Professor Pitblado's laboratory, were later analyzed for pH, alkalinity, conductivity, dissolved organic carbon, chlorophyll a, suspended solids, total P, Kjeldahl N, sulphate, calcium, magnesium, iron, aluminium, copper, and nickel. The analyses were performed by laboratories of the Ministry of the Environment in Thunder Bay and Toronto. The results of all these investigations, together with data from the Ontario Geological Survey component, will be discussed in a report due to be completed in 1987.

THE ONTARIO GEOLOGICAL SURVEY COMPONENT

The geochemical studies, completed by the Ontario Geological Survey, involved visits to 150 lake sites in the Sudbury area, and 150 lake sites in the Algoma area. The objectives of the studies were to:

1. Complete aa mineral resource appraisal geochemical study of an area northeast of Sudbury, 75 km (north-south) by 10 km (east-west), extending north from Lake Wanapitei.
2. Complete aa mineral resource appraisal geochemical study on an area in the District of Algoma, 40 km (north-south) by 15 km (east-west), extending south from the Montreal River.
3. To co-ordinate the interdisciplinary report on the project for publication by the Ontario Geological Survey in 1987.

METHODOLOGY

The general methodology used for the two geochemical surveys was similar to that described for the Opapimiskan Lake project (Fortescue and Webb, this volume) but included several important changes in technique. One was to collect 4 litre water samples at each lake site in order to provide enough water for the analytical program carried through by the Ontario Ministry of the Environment (*see* above). A second technique change was to collect lake sediment cores from each lake sample site. The cores were collected by a simple gravity corer and were usually between 25 and 35 cm long. As many as 40 cores could be collected by a two-man crew in a Bell 206 helicopter during a day's work. The cores were extruded to provide 4 subsamples, which were stored in separate 2 ounce (57 ml) vials, each vial containing approximately five centimetres of core-sample sediment. Two of the samples were of Post-*Ambrosia* material (i.e. sediment less than 100 years old) and two were Pre-*Ambrosia* material (i.e. sediment laid down prior to modern man's entry into northern Ontario). The purpose of the Pre-*Ambrosia* and Post-*Ambrosia* samples was to produce two sets of mineral resource appraisal-type data maps for each of the two areas. The Pre-*Ambrosia* samples were to be used for normal mineral resource appraisal geochemical maps, and the Post-*Ambrosia* samples for maps showing elements which were known to accumulate significantly in recent sediments as a result of atmospheric fallout (e.g. nickel and copper in the Sudbury area, Fortescue 1985). The lake sediment samples from the Algoma and Sudbury test sites are currently being subjected to chemical analysis for over 25 elements by a contractor in Toronto.

An advantage of the collection of lake sediment cores was that it could be used to discover lakes with anoxic bottoms of the type suitable for detailed diatom-inferred pH measurements (M. Dickman, Professor, Brock University, St. Catharines, personal communication 1986). It is desirable that such measurements be made from material which has not been significantly bioturbated so that the recent pH history of the lakes can be described. This is particularly important because the recovery of acid lakes during the past few years has been reported in the literature (Keller and Pitblado 1986).

PRELIMINARY RESULTS

The pH of lake waters, sampled during the Algoma geochemical survey, are indicated on Figure 052.1, where the position of each lake sample site is indicated by a dot. Circles around some of the dots indicate lakes from which helicopterborne radiometer measurements were made on days when the sky was clear and the Landsat 5 satellite flew over the study areas. The numbers in the circles refer to the pH of lake waters measured within 24 hours of sample collection. In general, the pH pattern in the sampled area was such that lakes in the north exhibited a pH less than 6.0, while lakes in the south of the area generally had pH values greater than 6.0. Within the northern group of lakes, especially around Barbara Lake, a cluster of lakes with pH values below 5.0 was found. Some of these low pH lakes were very clear and are considered likely to be sensitive to acid precipitation effects. Further interpretation of these data will continue throughout the winter months as more chemical data accumulates.

SUMMARY

A fully interdisciplinary study of over 300 lakes in two areas of the Canadian Shield has been completed involving geochemistry, limnology, and remote sensing. Preliminary results from one of the field areas revealed a cluster of acid lakes, some with humic waters, and others with clear waters; the latter being lakes of the type known to be sensitive to inputs of acid precipitation. A comprehensive report describing the interdisciplinary study as a whole is planned for 1987, together with two geochemical map sheets; one for the Sudbury test site and the other for that at Algoma.

ACKNOWLEDGMENTS

The authors would like to thank all members of the team for their co-operation during the planning of the project and in the field. In particular, they would like to thank Len MacTaggart, of Lakeland Helicopters, Sudbury, for close co-operation with the team at all times especially during quick changes of plan dictated by changes in weather conditions.

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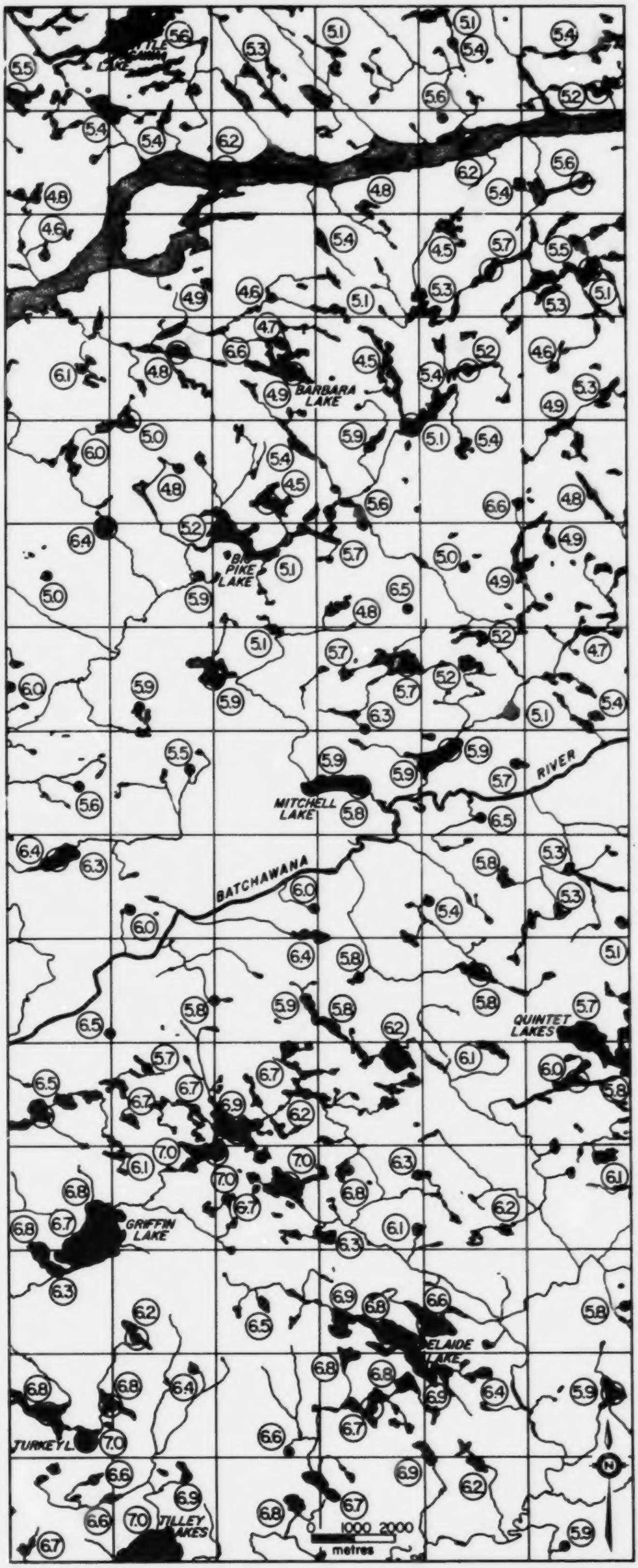
LITTLE AGAWA LAKE
BARBARA LAKE
BIG PIKE LAKE
RIVER
MITCHELL LAKE
BATCHAWANA
QUINTET LAKES
GRIFFIN LAKE
ADELAIDE LAKE
TURKEY L.
TILLEY LAKES
N
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metres
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Figure 052.1. Values for pH of lake waters sampled during Algoma survey. See text for detail.

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MINERAL DEPOSITS PROGRAMS

053. Summary of Activities 1986, Mineral Deposits Section

A.C. Colvine

Section Chief, Mineral Deposits Section, Ontario Geological Survey, Toronto.

The major emphasis of the Mineral Deposits Section in 1986 continued to be the investigation of Archean lode gold deposits. Despite this emphasis, the Section was able to expand its initiatives to document the industrial mineral potential of Ontario, in part through cooperative work with staff from the regional offices of the Ontario Ministry of Northern Development and Mines.

In addition, Section staff monitored a broad coverage of the full range of Ontario's mineral resources. Particular emphasis was placed on platinum group elements and a report on "Platinum in Ontario" is in preparation. Further work was initiated on the Proterozoic Huronian Supergroup to further document features pertinent to gold potential reported by Long, Colvine, and others over the past few years (Colvine 1985).

Project descriptions, progress reports, and funding sources are contained in individual reports; several of the projects initiated in 1986 were funded under the Canada-Ontario Mineral Development Agreement (COMDA).

The Archean gold program, which was initiated in 1980, has, since 1984, been twofold in purpose:

1. to develop and refine a genetic model for lode gold deposits (Colvine *et al.* 1984) by the thorough documentation of the geology of major gold deposits and gold camps
2. to apply this model to greenstone terrains with little past gold production, but with good potential for gold

Major programs directed toward the first objective in the Red Lake (Andrews and Hugon 1985), Beardmore-Geraldton (Macdonald 1984), and Abitibi (Marmont 1984) greenstone belts are now approaching completion. Results from these programs were presented (Andrews *et al.* 1986, Marmont 1986) in September at Gold '86, an international symposium held in Toronto.

A number of projects directed toward the second objective continued in 1986 (Smith and Thomas, this volume; Fyon and O'Donnell, this volume; Heather, this volume; Piroshco, this volume; Whittaker, this volume; Malczak, this volume; Troop, this volume). Others were completed (Chorlton, in preparation) or initiated (Melling, this volume; Buck, this volume) in 1986. Each of these projects contribute refinements to the genetic model for Archean lode gold deposits; at the same time, each expands the geological database requisite for efficient mineral exploration within its area.

The intent of the Mineral Deposits Section to begin a program in industrial minerals, outlined in Colvine (1985), is evident in the number of such projects reported upon in this volume. These projects range from northern Ontario (Ford, Springer, and Vos) to the Grenville Province in eastern Ontario (Churcher, and Di Prisco). Several are being conducted cooperatively with staff in regional offices (Marmont, Verschuren, Williams and Thompson, and MacKinnon). A wide variety of industrial mineral commodities, ranging from residual apatite to be used as a source of phosphorus in fertilizer, through resources for refractories, to expandable clays for use as aggregate, are being examined. Documentation of the possibilities for development in Ontario, within the vast industrial minerals industry, will be a priority of the Mineral Deposits Section.

Staff of the Mineral Deposits Section reported on their projects at a number of conferences, including the annual meetings of the Geological Society of America, and the Geological and Mineralogical Associations of Canada, at a symposium on gold at Southampton, England, and at Gold '86. Staff of the Section also led several field trips which were held as part of Gold '86.

Ontario Geological Survey publications by the Mineral Deposits Section in 1986 include:

1. Ceramic Properties of Selected Shale and Clay Resources of South Central Ontario; Open File Report 5571.
2. Talc, Magnesite and Asbestos Deposits of the Kirkland Lake-Timmins Area, Districts of Timiskaming and Cochrane; Study 28.

3. Geology and Ceramic Properties of Selected Shales and Clays of Southwestern Ontario; Open File Report 5583.
4. Assessment of the Gold Potential in the Uchi-Confederation-Woman Lakes Area: Preliminary Results, District of Kenora, Patricia Portion; Preliminary Map P.2989.
5. Exploration Potential for Base and Precious Metal Mineralization in Part of Strathy Township, Temagami Area; Open File Report 5591.
6. The Placer Gold Potential of the Early Aphebian Gowganda Formation Along the Northern Margin of the Cobalt Embayment, Ontario, with Comments on Associated Concentrations of Silver and Copper; Open File Report 5608.
7. Chromite Deposits in Ontario; Study 55.
8. Precambrian Geology of Huronian Strata in Part of the Northwestern Cobalt Plain, including Sheard, Ogilvie, Amyot, Browning, Hodgetts, Unwin, Lampman, Leask, and parts of North Williams, Dufferin, Stull, Valin, and Marshay Townships, Timiskaming and Sudbury Districts; Preliminary Map P.3048.

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054. Interrelationship of Gold Mineralization and the Canoe Lake Stock, Northwestern Lake of the Woods Area

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[2]Undergraduate Student, Department of Earth Sciences, University of Waterloo, Waterloo.

This Project is Part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a Subsidiary Agreement to the Economic and Regional Development Agreement (ERDA) signed by the Governments of Canada and Ontario.

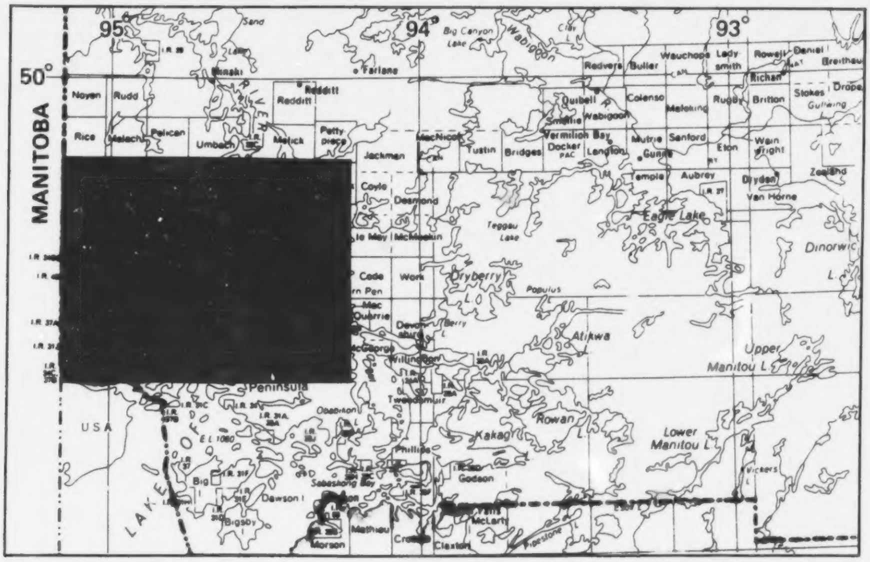
INTRODUCTION

A three-year project was initiated in the spring of 1986 to supplement an earlier study of gold mineralization in the Lake of the Woods area (Davies 1983; Davies and Smith 1984; Smith 1984; Davies and Smith, in preparation). Whereas the earlier study comprised an extensive compilation of data from known gold occurrences, it is the intention of this study to define the nature and controls of gold mineralization in the region, in order to delimit potential areas for gold exploration.

Gold mineralization in the region has been discussed by Blackburn and Janes (1983), Davies (1983), Davies and Smith (1984), and Smith (1984, 1985, 1986). These authors recognized that gold was hosted within veins and/or silicified shear zones, with a preferred site being basaltic and ultramafic rocks which are low in the stratigraphic sequence.

During the 1986 field season, the strain, alteration, and metamorphic patterns in rocks surrounding the Canoe Lake Stock were examined. This area was chosen for three reasons: 1) a spatial relationship has been noted between certain late granitic bodies and gold mineralization in specific domains within the Lake of the Woods area (Colvine and Sutherland 1979; Pedora 1976; Smith 1986); 2) the Canoe Lake Stock is the only such intrusion in the area which is completely contained within the greenstone belt and does not cross provincial boundaries; and 3) exploration is active in the area. Previous workers have suggested porphyry-type analogies for the emplacement of, and mineralization within, the Canoe Lake Stock (Campbell 1973; Davies 1978). Colvine and Sutherland (1979) indicated that gold mineralization proximal to the stock may have been remobilized into structures during its emplacement, and that the highest concentration of gold along the southwestern flank of the stock could be due to intrusion into specific favourable mafic rocks.

Two separate study areas were examined during the 1986 field season. Area 1 (the Bag Bay-Helldiver Bay area) lies roughly 40 km southwest of Kenora in Glass Township, immediately south of Bag Bay, Shoal Lake (Figure 054.1). This domain is within a low strain shadow extending southwest from the Canoe Lake Stock (Smith 1986), and is host to the second and fifth largest past producers in the Kenora area, in addition to numerous small occurrences and prospects. Davies (1978) and Davies and Smith (1984) suggested that the complicated faulting pattern evident throughout this area has been affected by the emplacement of the Canoe Lake Stock. Examination of this area was instigated to determine what, if any,



LOCATION MAP   Scale : 1:1 584 000 or 1 inch to 25 miles

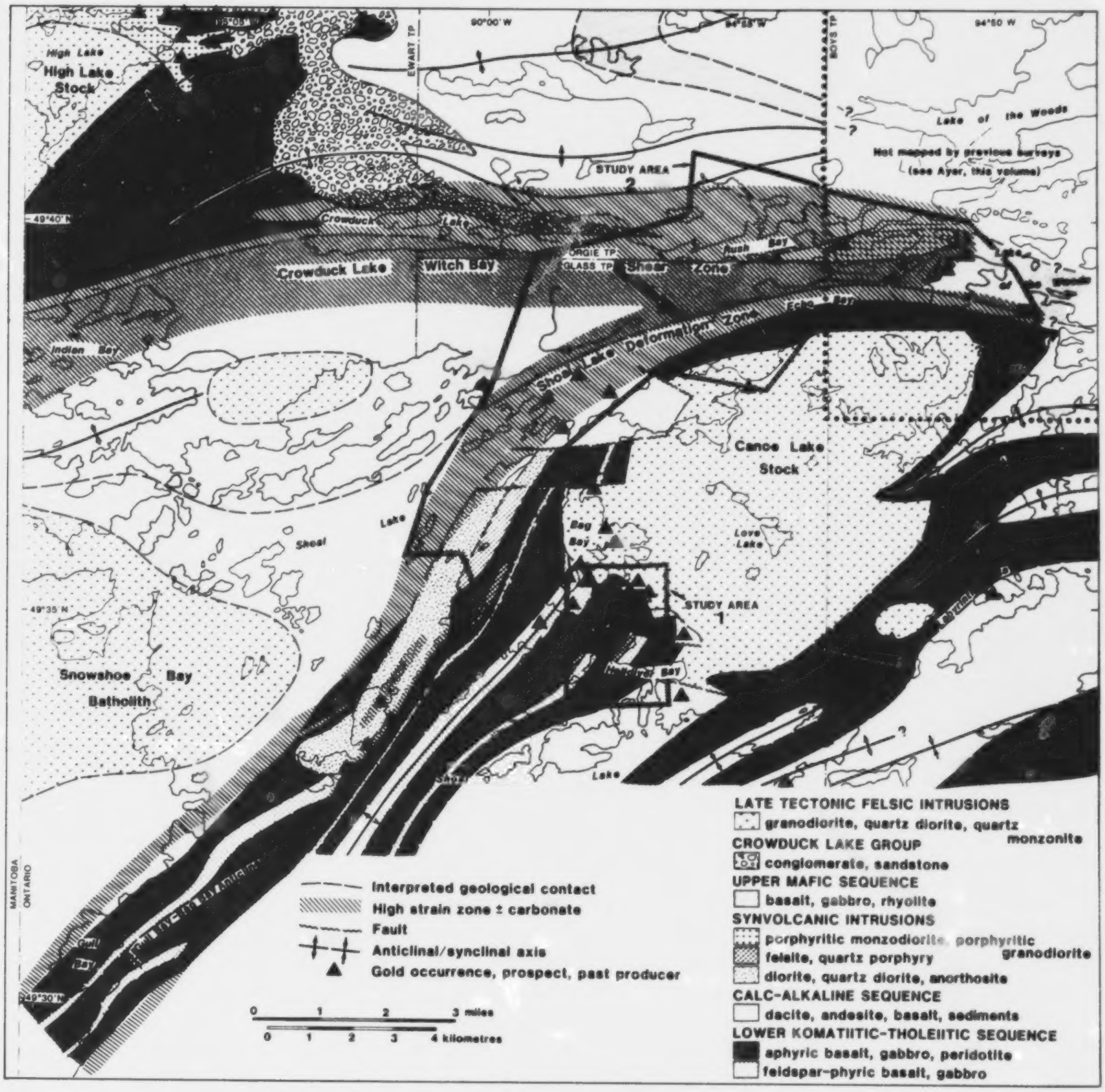

High Lake
High Lake Stock
90°00' W
94°55' W
94°50 W
EWART TP
BOYS TP
Lake of the Woods
Not mapped by previous surveys (see Ayer, this volume)
STUDY AREA 2
49°40' N
Crowduck Lake
Crowduck Lake
Witch Bay
FORGIE TP
GLASS TP
Shear Zone
Rush Bay
Echo Bay
Shoal Lake Deformation Zone
Indian Bay
Canoe Lake Stock
Love Lake
Shoal Lake
Bag Bay
STUDY AREA 1
49°35' N
Snowshoe Bay Batholith
Lake
MANITOBA
ONTARIO
49°30' N
Interpreted geological contact
High strain zone ± carbonate
Fault
Anticlinal/synclinal axis
Gold occurrence, prospect, past producer
0 1 2 3 miles
0 1 2 3 4 kilometres
LATE TECTONIC FELSIC INTRUSIONS
granodiorite, quartz diorite, quartz monzonite
CROWDUCK LAKE GROUP
conglomerate, sandstone
UPPER MAFIC SEQUENCE
basalt, gabbro, rhyolite
SYNVOLCANIC INTRUSIONS
porphyritic monzodiorite, porphyritic granodiorite
felsite, quartz porphyry
diorite, quartz diorite, anorthosite
CALC-ALKALINE SEQUENCE
dacite, andesite, basalt, sediments
LOWER KOMATIITIC-THOLEIITIC SEQUENCE
aphyric basalt, gabbro, peridotite
feldspar-phyric basalt, gabbro

Figure 054.1. *Generalized geology in the Shoal Lake, Labyrinth Bay and Rush Bay areas. Modified from Davies (1965, 1978), and Smith (1986).*

were the effects of these fault systems on gold mineralization.

Area 2 (the Rush Bay-Clytie Bay area) includes portions of Boys, Forgie, and Glass Townships and extends south into Shoal Lake (Figure 054.1). It lies along the northern and western flanks of the Canoe Lake Stock, and includes segments of the Shoal Lake Deformation Zone (Smith 1986) and the Crowduck Lake-Witch Bay Shear Zone (Ayer 1985) along which are located numerous gold occurrences, including several past producers. This domain was chosen to examine the relationship between the Canoe Lake Stock and surrounding high strain zones. Furthermore, it was hoped that by examining the fabrics within these high-strain zones an understanding of the kinematics within the region could be established. Finally, as the intersection of the two deformation zones lies within this domain, temporal relations between the two zones may also be determined.

REGIONAL GEOLOGY

The regional geology of the area has been discussed by Goodwin (1965, 1970, 1984), Blackburn *et al.* (1985), and Smith (1986). In general, the stratigraphy in the Lake of the Woods area may be subdivided into a lower mafic komatiitic-tholeiitic sequence, overlain by a mixed calc-alkaline, mafic-felsic sequence with intercalated volcanogenic and chemical sediments; in places, a second mafic tholeiitic sequence overlies the calc-alkaline rocks (Goodwin 1984; Blackburn *et al.* 1985; Smith 1986). Younger conglomerates and wackes unconformably overlie the volcanic package (Beakhouse 1985; Davies *et al.* 1985).

The volcanic and sedimentary sequences have been intruded by numerous granitoid bodies, some of which reach batholithic dimensions. These are of two types, either syn-volcanic or late tectonic (Blackburn *et al.* 1985). Numerous felsic dikes intrude the volcano-sedimentary package and are probably related to both early volcanism and later intrusive events. Lamprophyre dikes intrude all lithologies and are clearly late.

The structural history of the area is complex. In general, two possibly overlapping periods of deformation have been identified (Schwerdtner *et al.* 1979). An earlier period of dominantly vertical tectonics, related to the emplacement of large granitoid batholiths, appears responsible for most of the major folding within the greenstone belt. A late period of large-scale shearing was active after plutonism and seems to result from a major northwest-southeast principal compression.

THE BAG BAY–HELLDIVER BAY AREA

This area encompasses numerous gold occurrences, eight prospects, and three past producers (Figure 054.2): the Mikado (28 335 ounces), Cedar Island (Cornucopia) (4941 ounces), and Olympia Mines (332 ounces) (Beard and Garratt 1976). The area is underlain by rocks of the lower komatiitic-tholeiitic sequence (Smith 1984, 1985, 1986) and extends east from the axial trace of the Gull Bay-Bag Bay Anticline into the southwestern margin of the Canoe Lake Stock (Figure 054.2).

STRATIGRAPHY

The stratigraphy of the area, summarized in Table 054.1, is virtually identical to that on the western limb of the Gull Bay-Bag Bay Anticline (Smith 1985, 1986). Two feldspar-phyric basaltic units are exposed in the study area, and serve as excellent marker horizons. The size of the feldspar phenocrysts appears to decrease towards the top of both feldspar-phyric units, similar to grain size changes observed on the west limb of the Gull Bay-Bag Bay Anticline (Smith 1986). The phenocrysts do not extend through pillow rims and are broken where they are in hyaloclastite.

LATE INTRUSIONS

The Canoe Lake Stock has been described by Colvine and Sutherland (1979). It is a heterogeneous quartz diorite body, elongated northwest, with a length of 11 km and width of 8 km. The rocks vary from medium- to coarse-grained, equigranular quartz diorite to fine- to coarse-grained porphyritic quartz diorite. Locally there are pegmatitic and aplitic phases. Colvine and Sutherland (1979) observed strong colour variations and variable mafic content (from 2 to 15 percent) with no apparent pattern. Abundant xenoliths of volcanic rock have been observed locally, including large blocks near the centre of the intrusion near Love Lake. Reaction rims on the inclusions indicate assimilation (Colvine and Sutherland 1979), which in places is so strong that only a ghost of the original contact relationships may be recognized. Xenoliths have a northeast preferred orientation (Colvine and Sutherland 1979), which is consistent with fabric orientation near the margins of the stock. Campbell (1973), who completed petrographic and geochemical studies of quartz diorite from various locations within the stock, defined a variable mineralogy, consisting of 45 to 70 percent andesine feldspar, 15 to 50 percent quartz and up to 15 percent combined biotite and hornblende. Sphene, rutile, and apatite are accessory minerals and magnetite and ilmenite are present in trace amounts. Minor hematite occurs as stringers. The intrusion, which has a tentative U-Pb zircon age of 2.708 Ga (D. Davies, Geochronologist, University of Toronto, personal communication, 1985), is contemporaneous with, or later than, the development of the Gull Bay-Bag Bay Anticline, which is deflected and truncated at the margin of the stock under Bag Bay (Figure 054.1). Fine-grained felsite, quartz-feldspar porphyry, quartz diorite and pegmatite dikes intrude both the stock and the surrounding volcanic rocks, but are interpreted to be related to the same intrusive event (Colvine and Sutherland 1979). The pegmatite dikes cut the other felsic dikes and are interpreted to be the youngest phase of the intrusion. Lamprophyre dikes are the youngest intrusions in the area and cut the pegmatite dikes.

METAMORPHISM AND ALTERATION

Most of the area has been metamorphosed to greenschist facies. In places, cores of pillows are preferentially epidotized and interpillow material is quartz- and epidote-rich, indicative of sub-seafloor alteration. An amphibolite-grade metamorphic aureole extends at least 400 m southwest of the Canoe Lake Stock. Epidote replacement of feldspar, and epidote fracture fill are particularly strong within the volcanic rocks proximal to the Canoe Lake Stock. This epidotization appears spatially related to the intrusion; however, it is cut by quartz diorite and pegmatitic dikes and veinlets. Most of the gold occurrences in the study area lie close to, or within, the amphibolite-grade aureole, including the Mikado and Cedar Island Mines. In general, these occurrences are characterized by visible quartz and carbonate, with or without sulphide mineralization, biotite, and green muscovite. Quartz and carbonate occur within both veins and discrete alteration haloes. Although much of the gold is located within the amphibolite-grade aureole of the stock, it is not clear whether this gold mineralization, and the alteration which is spatially associated with it, are related to the peak metamorphism, or a later overprinting retrograde event. Detailed petrography of vein-related alteration should aid in distinguishing such temporal relationships.

STRUCTURE

At least two specific periods of deformation characterize the area. An early period of folding (D_1) has resulted in the development of the northeast-trending Gull Bay-Bag Bay Anticline (Figures 054.1 and 054.2).

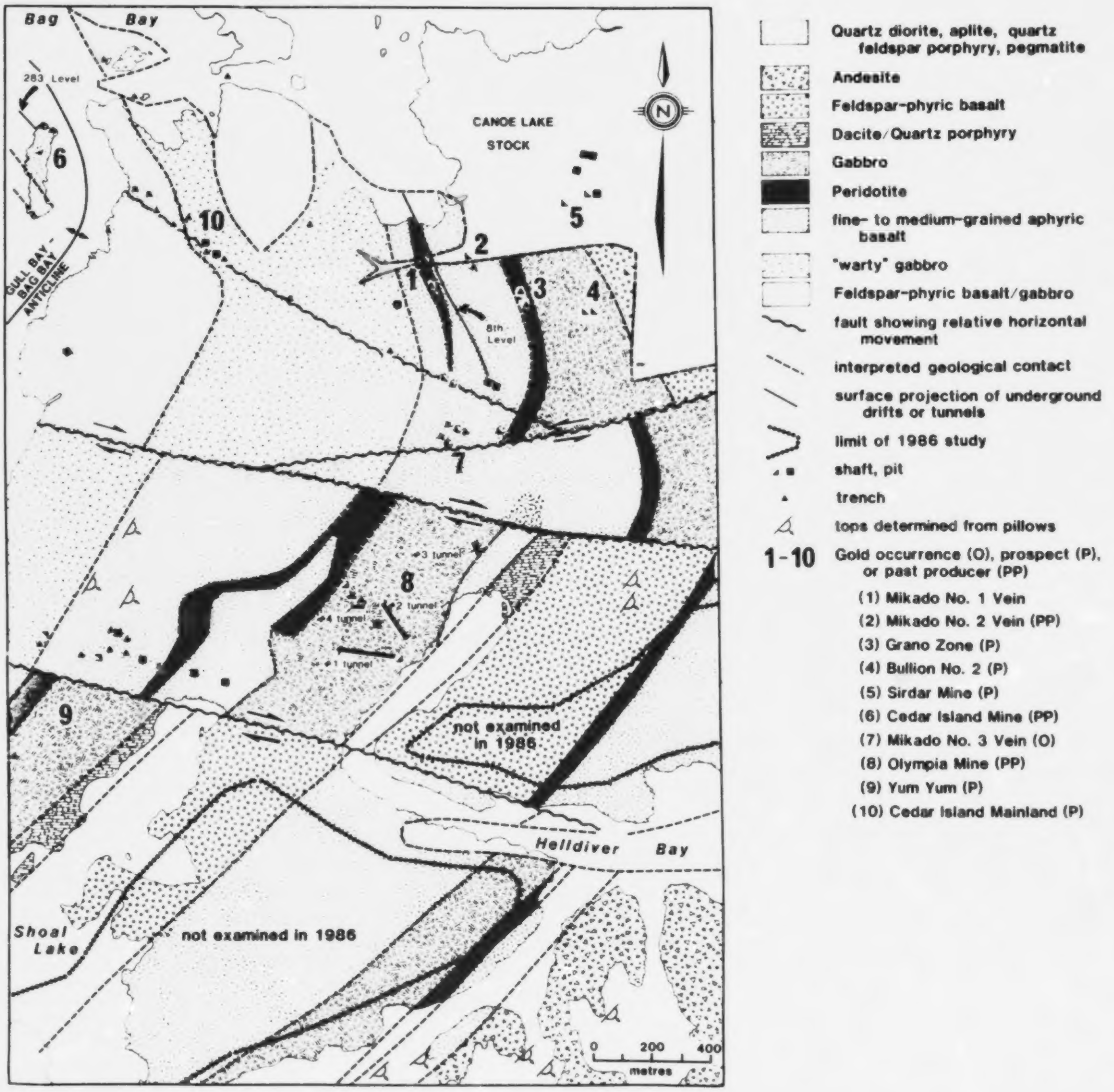

Bag Bay
283 Level
6
GULL BAY - BAG BAY ANTICLINE
10
CANOE LAKE STOCK
N
5
2
1
3
4
8th Level
7
#3 tunnel
8
#2 tunnel
#4 tunnel
#1 tunnel
9
not examined in 1986
Helldiver Bay
Shoal Lake
not examined in 1986
0 200 400 metres
Quartz diorite, aplite, quartz feldspar porphyry, pegmatite
Andesite
Feldspar-phyric basalt
Dacite/Quartz porphyry
Gabbro
Peridotite
fine- to medium-grained aphyric basalt
"warty" gabbro
Feldspar-phyric basalt/gabbro
fault showing relative horizontal movement
interpreted geological contact
surface projection of underground drifts or tunnels
limit of 1986 study
shaft, pit
trench
tops determined from pillows
1-10 Gold occurrence (O), prospect (P), or past producer (PP)
(1) Mikado No. 1 Vein
(2) Mikado No. 2 Vein (PP)
(3) Grano Zone (P)
(4) Bullion No. 2 (P)
(5) Sirdar Mine (P)
(6) Cedar Island Mine (PP)
(7) Mikado No. 3 Vein (O)
(8) Olympia Mine (PP)
(9) Yum Yum (P)
(10) Cedar Island Mainland (P)

Figure 054.2. *Generalized geology of the Bag Bay-Helldiver Bay area. Note that underground projections are directly above workings, and are not extrapolated along the veins to surface. This is particularly evident at the Mikado # 1 vein, since surface exposure of the vein is within the peridotite unit.*

This is an open fold with the limbs dipping 60° to 70° southeast and northwest. In general, there are no distinct fabrics related to this folding event, although a sub-vertical stretching lineation, developed locally within the feldspar-phyric basalt units, may be. A later period of dominantly brittle faulting (D_2) has resulted in horizontal offsets of lithological contacts up to 600 m (Figure 054.1 and 054.2). This faulting has been accompanied by a westward deflection of the volcanic units in the northern portion of the area, within the amphibolite aureole of the Canoe Lake Stock.

East-northeast- and east-southeast-trending lineaments are evident on the aerial photographs of the area, and are the surface expressions of the D_2 faults (Figures 054.1 and 054.2). Northwest- to north-northeast-trending lineaments express lithological contacts. There is no exposure along most of the major easterly trending lineaments, thus fabric analysis is not possible, although splays or subsidiary shears are exposed locally. Instead, since the stratigraphy is consistent throughout the study area, kinematics, particularly the sense of horizontal displacement, can be determined from the displacement of units.

Most of the displacement along the D_2 faults occurs in the central eastern portion of the area (Figure 054.2). The displacement is both sinistral and dextral along marginal faults which isolate undeformed wedges of volcanic rock. Displacement also

TABLE 054.1: STRATIGRAPHY OF THE BAG BAY–HELLDIVER BAY AREA EAST OF THE GULL BAY–BAG BAY ANTICLINE. SEE FIGURE 054.2 FOR LOCATION.

Lithology	Description
Calc-alkaline sequence	
Andesite	Intercalated crystal tuff, tuff breccia, and pillowed flows.
Lower Komatiitic-Tholeiitic Sequence	
Gabbro/pyroxenite	Medium- to coarse-grained gabbro, locally pyroxenite, near the eastern margin of the unit.
Aphyric Basalt	Massive, fine- to medium-grained basalt, locally spinifex texture.
Feldspar-phyric Basalt	Up to 4 cm subhedral to euhedral feldspar phenocrysts in a fine- to medium-grained matrix. Locally pillowed.
Gabbro/Peridotite	Eastward differentiating gabbro sill. Peridotite is in sharp contact to the east with melagabbro, which locally grades eastwards into leucogabbro. Thickness of the peridotite varies, possibly as a result of original contact relationships.
Dacite/Quartz Porphyry	Highly fractured, massive felsic rock contains abundant 1 to 2 mm quartz eyes and displays no primary volcanic textures. May be a flow or subvolcanic sill.
Aphyric Basalt	Fine- to medium-grained massive and pillowed basalts are komatiitic in composition (Davies and Smith, in preparation). Narrow stratabound, or strataform peridotite units occur in places. Near the Canoe Lake stock epidote "warts" occur in coarser phases.
"Warty" Gabbro Flow/Sill	Medium-grained gabbro contains abundant glomerocrysts of feldspar up to 1 cm. These are epidotized proximal to the Canoe Lake stock, and stand up in relief relative to the surrounding matrix, creating a knotted rough surface which has a wart-like appearance. Contacts of this unit, where observed, are sheared, and varioles occur locally near the base. The unit is slightly finer grained near the middle and may be either two thick flows, or two subvolcanic sills.
Feldspar-phyric Basalt/Gabbro	Subhedral to euhedral feldspar phenocrysts up to 4 cm, hosted in a medium- to coarse-grained gabbroid matrix. Locally intercalated with non-porphyritic horizons. Banded sulphide iron formations occur locally near the top of this unit.

appears to decrease westward, beyond the study area, likely indicating a rotational component as well as vertical and horizontal translations, wherein the stock-side moves upwards in a central wedge. Most likely, some of the horizontal displacement is apparent, since any upward movement of portions of the eastern limb of the Gull Bay-Bag Bay Anticline would result in an apparent eastward displacement of the lithologies. Slickensides and "C" and "C′" fabrics (terminology after Berthe *et al.* 1979; Simpson and Schmid 1983; Lister and Snoke 1984; Simpson 1984), developed in some subsidiary shear zones, indicate a component of sub-horizontal movement.

A number of gold occurrences appear to be hosted within, or proximal to, the easterly trending fault systems. These include the Cedar Island Mainland Prospect, the Yum Yum Prospect and the Mikado #3 vein. The Olympia Mine has brecciated vein systems which lie in a similar orientation and may be along subsidiary zones. Drilling by St. Joe Canada Incorporated on the Cedar Island Mainland Prospect indicates that it may have substantial strike length (Kevin Leonard, Geologist, St. Joe Canada Incorporated, personal communication, 1986).

A second, more subtle, system of shear zones related to the D_2 event is developed proximal to stratigraphic contacts. The Mikado Mine #1 vein system is hosted by one of these northwest-trending zones. Where exposed, this vein system is within narrow, left-stepping, sinistral shears which are hosted by a narrow peridotite unit bounded to the east and west by komatiitic basalt (Figure 054.2). The vein system dips approximately 75° west, and transects a 50 m wide, shallowly south-dipping apophysis of the Canoe Lake Stock. The apophysis has a quartz diorite margin and a red pegmatite core.

Shear zones which trace lithological contacts probably developed in response to the deflection of the host volcanic rocks caused by the intrusion of the western lobe of the Canoe Lake Stock which underlies Bag Bay (Figure 054.2). Such shears could result from greater flexure of units closer to the core of the fold. As a result, there may have been differential stress developed between adjacent volcanic units, and shears would have formed to release applied stress. Strain would be particularly concentrated where ductility contrasts exist between lithologies.

In the case of the Mikado #1 vein, the peridotite likely behaved more ductilely than the surrounding basalts. Two other veins on the Mikado Property (the #2 vein and the Grano Zone) may have developed in a similar manner. Although the exposure along these vein systems is poor, both parallel the #1 vein, and the Grano Zone also lies along strike from a peridotite unit (Figure 054.2). Similarly, although the vein systems at the Cedar Island Mine are not exposed, the orientation of the underground development is parallel to the lithological contacts on the mainland, and to the contact between feldspar-phyric and aphyric basalts near the southern end of the island (Figure 054.2).

GOLD MINERALIZATION

Historically, most of the gold produced at the Mikado Mine was from quartz, extracted where the #1 vein system intersects the apophysis of the Canoe Lake Stock. There, well defined veins, reaching widths up to 4.5 m (Davies 1978), were mined to a depth of 180 m and accessed from ten levels. Production appears to have been concentrated within the intrusion because of the increased vein width and the type of host rock. There is no indication that the grade of the deposit increased within the apophysis; Bruce (1925) observed that grades were at least as rich within the volcanic rocks (greenstone), and it was suggested that there were significant recovery problems when milling the volcanic rocks (The Canadian Mining Review 1900, p.216). Kenora Miners and Prospectors Limited is presently attempting to recover the gold remaining in the tailings (Sue Dobson, President, Kenora Miners and Prospectors Limited, personal communication, 1986). The #1 vein, where exposed within peridotite on the surface, occurs as narrow (up to 10 cm wide) *en echelon* quartz veins in narrow, left-stepping, discrete shears. Where hosted by the intrusion, the main vein has been mined to surface and is not presently exposed; however, the wall rock is locally brecciated and riddled with narrow quartz veins up to 2 m from the mouth of the inclined shaft. Widening of the vein system within the intrusion may have resulted from a competency contrast. The intrusion likely behaved more brittlely than the host volcanics.

Visible wall rock alteration proximal to the Mikado #1 and #2 veins includes weak carbonatization, silicification, and biotitization. Native gold occurs within the vein and silicified wall rock as small grains in the gangue and as "leaf" gold along slip planes. Vein sulphides include pyrite, chalcopyrite, molybdenite, and bismuthinite. Davies (1978) also noted the presence of galena and tetradymite (Bi_2Te_2S). Samples were taken during this program to determine the extent and timing of alteration and metamorphism, and to attempt to delimit the composition of the mineralizing fluid.

Similar, but more pervasive alteration assemblages surround the vein systems hosted within the easterly brittle fault systems. These include the Mikado #3 vein, the Cedar Island Mainland Prospect, part of the Yum Yum Prospect, and probably several of the Olympia veins (Figure 054.2). There, carbonatization is more pervasive, and quartz occurs locally as fracture fill and breccia matrix, in addition to discrete silicified zones. Sulphide mineralization (chiefly pyrite) is locally abundant, and trenches, where presently exposed, are generally highly gossanous. A similar sampling and analytical program to that at the Mikado Mine # 1 and 2 veins has been undertaken here for comparison purposes.

Some vein systems, like the Sirdar Prospect (Figure 054.2), are hosted by shears within the margin of the stock. Surface exposure is poor at these occurrences, and additional work is necessary to ascertain their significance.

DISCUSSION

Temporal relationships evident in the Bag Bay-Helldiver Bay area are summarized in Figure 054.3. The shallow-water deposition (Davies 1978) of early mafic and felsic volcanic rocks was followed by a period of isoclinal folding in which the Gull Bay-Bag Bay Anticline was developed. Subsequent intrusion of the Canoe Lake Stock cut through and deflected the anticlinal axis, and intruded both the mafic and felsic sequences. Gold appears to be located in structures which were developed and/or modified during the emplacement of the stock. Gold-bearing zones are generally characterized by abundant felsic dikes. Gold deposition is late, transecting pegmatitic dikes which are interpreted to be associated with a late phase of the Canoe Lake Stock. Additional petrography should further delineate such temporal relationships, particularly in terms of metamorphism and alteration. An origin of the gold can not be speculated upon at this point; however, there is a strong spatial relationship between the intrusion and the numerous gold occurrences developed along its flanks. It would seem likely that there is some direct correlation between gold mineralization and the emplacement event.

THE RUSH BAY–CLYTIE BAY AREA

The general geology of this area is discussed by Davies (1965, 1978). Most of the volcanic rocks in this domain have been strained; the intensity of the deformation is variable, and most of the strain is concentrated within two major deformation zones. In places, particularly within the cores of the sheared zones, it is not possible to distinguish the protolith due to the extreme deformation and the ubiquitous carbonatization which accompanies that deformation. Both mafic and felsic subvolcanic intrusions seem to be more resistant to the deformation, and form lithons of relatively undeformed rock within the high-strain zones. This study focused on examining fabrics which have developed within the Shoal Lake

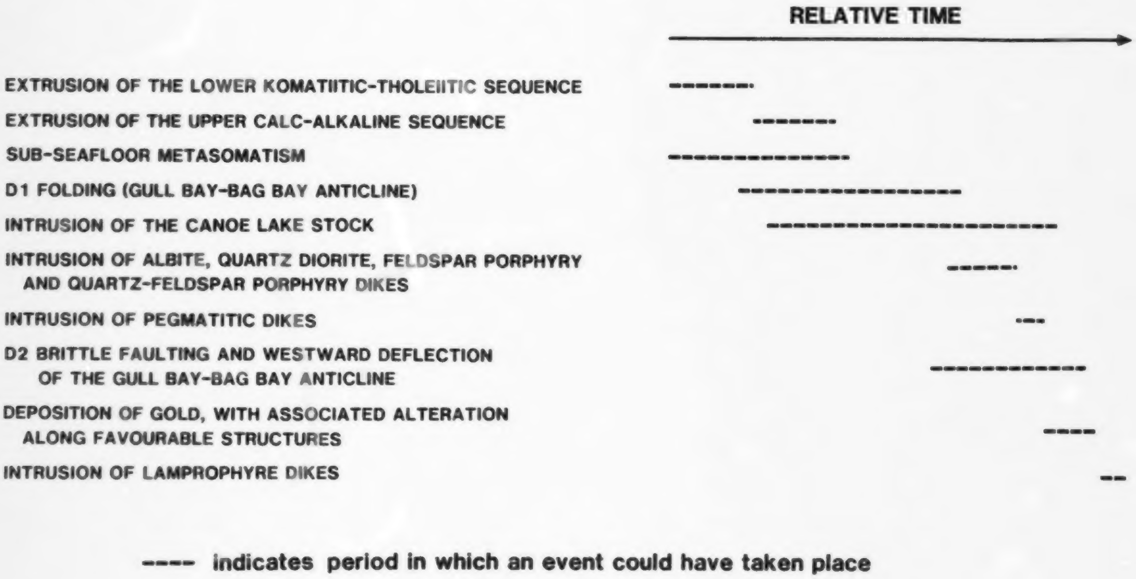


Figure 054.3. *Relative timing of events in the Bag Bay-Helldiver Bay area.*

Deformation Zone and the Crowduck Lake-Witch Bay Shear Zone (Figures 054.1) in an attempt to define the kinematics active during deformation.

CROWDUCK LAKE–WITCH BAY SHEAR ZONE

This intensely deformed zone has been traced at least 70 km from the Manitoba border east to Witch Bay, Lake of the Woods (Smith 1986). It has been suggested that relative movement along the zone was dextral (Davies and Smith 1984; Davies *et al.* 1985; Smith 1986), based on shear folds in the High Lake area and regional foliation trajectory diagrams, wherein a northeast-trending regional "S" fabric is deflected eastward into the "C" fabric developed within the deformed zone. Observations during the current field season confirmed these regional trends, but also identified additional periods of subvertical movement within the more intensely deformed regions.

Marginal areas of the sheared zone are characterized by the development of protomylonite, in which narrow, anastomosing shear planes up to several centimetres wide separate lithons of relatively undeformed rock. Shear planes display "S" and "C" fabric relationships in the horizontal plane which are indicative of dextral horizontal movement in a simple shear system. Although pillows located within this protomylonitic region are stretched, pillow selvages are easily recognized. Mineral lineations in this region generally pitch steeply northeast, and may have developed due to extension in response to a significant pure shear component which was active in the YZ plane of the strain ellipsoid. Alternatively, as these lineations appear to be colinear to the steeply plunging fold axis to north of the sheared zone, they may be related to that folding event. These lineations are not easily distinguished from mineral stretching lineations associated with simple shear. Furthermore, in places, distinct, well formed stretching lineations are shallowly dipping to sub-horizontal, which is consistent with sub-horizontal motion.

In the the more intensly strained sections of the Crowduck Lake-Witch Bay Shear Zone, along the northern margin of the Canoe Lake Stock and in the central portion of the main shear zone, "C" and "C′" fabrics are locally developed and also indicate sub-horizontal dextral movement. Lineations developed in these areas also pitch steeply northeast and may have been formed in a similar manner to that described above. Alternatively, these lineations may be a reflection of sub-vertical movement that might have occurred either before or after the dextral event. These possibilities are substantiated in places. Near the Canoe Lake Stock, "C" and "C′" fabrics were recognized which indicated south side up. "Timiskaming-type" sediments, consisting of coarse conglomerates and sandstones (Figure 054.1), unconformably overlie the volcanic rocks north of the sheared zone (Beakhouse 1985), and may represent early fault scarp-type sedimentation related to a period of south side up movement. These sediments are folded in the shear folds resulting from the dextral movement. Additional study is necessary to verify these hypotheses.

SHOAL LAKE DEFORMATION ZONE

The Shoal Lake Deformation Zone can be traced from Gull Bay to Echo Bay (Figure 054.1). Kinematics within the southern portion of this sheared zone have been discussed by Smith (1984, 1985, 1986). "C" and "C′" fabrics recognized within the northern extension of the Shoal Lake Deformation Zone indicate northwest side up movement, which is consistent with that observed to the south. Foliations measured within the deformed zone dip west and trend subparallel to the zone's margins. Sub-vertical, southwest- to northwest-pitching mineral stretching lineations, observed throughout the Shoal Lake Deformation Zone, are consistent with the reverse sense of movement.

The Shoal Lake Deformation Zone deflects eastward to the north until it merges with the Crowduck Lake-Witch Bay Shear Zone. Fabrics within the interface area are deflected around a small augen-shaped monzodiorite intrusion which is hosted by the Crowduck Lake-Witch Bay Shear Zone (Figure 054.1). This intrusion is characterized by rapakivi texture. The core of the intrusion is moderately to slightly deformed, while the margins have been strained into mylonites and ultramylonites. Medium-grained gabbro intrusions located near that area also retain primary textures in their cores. There is no evidence of modification of the Shoal Lake Deformation Zone by the Crowduck Lake-Witch Bay Shear Zone, or vice versa. The transition from one strain environment to the the other appears gradational, and the two are likely contemporaneous.

EFFECT OF THE CANOE LAKE STOCK ON THE HIGH-STRAIN ZONES

No definitive indicators have been found to establish the relationship between the Canoe Lake Stock and the surrounding high-strain zones. In general, mineral lineations pitch away from the intrusion, possibly indicating modification of those strain zones by the intrusion. However, this is unlikely, particularly as lineations within the Crowduck Lake-Witch Bay Shear Zone and Shoal Lake Deformation Zone have similar orientations tens of kilometres from the intrusion. There is a weak fabric developed within the margin of the stock that could be either the foliation within the surrounding shear zones, or an internal flow foliation. Fabrics indicating that the intrusion side has moved up have been recognized within the Crowduck Lake-Rush Bay Shear Zone (discussed above). No such kinematic indicators were recognized within the Shoal Lake Deformation Zone. Additional work is necessary within the intrusion to define temporal relationships.

GOLD MINERALIZATION

All known gold mineralization in the Rush Bay-Clytie Bay area is hosted by the high-strain zones. The majority of these occurrences were examined by Davies and Smith (in preparation). Most of these occurrences are small, and there is only one past producer in the study area; the Golden Horn Mine produced 113 ounces of gold (Beard and Garratt 1976). In all cases, the occurrences lie within 3 km of the Canoe Lake Stock. In general, the gold is hosted within discrete veins or silicified shears which trend parallel to subparallel to the foliation, and are located along the margins of the strain-resistant gabbro and monzodiorite intrusions. Other than the spatial relationship, there is no evidence which clearly associates the gold mineralization with the Canoe Lake Stock. Most of the strained rocks are pervasively carbonatized and there is no visible amphibolite aureole extending north from the intrusion. The immediate western boundary of the intrusion has not yet been studied. Further petrography may aid in identifying evidence of earlier metamorphism.

DISCUSSION

The west side up and dextral movements within the Shoal Lake Deformation Zone and the Crowduck Lake-Witch Bay Shear Zone could have been developed during a single north to northwest compression. Furthermore, it is possible that these high-strain zones were concentrated along zones of pre-existing weakness. The contact between the lower tholeiitic-komatiitic, and upper calc-alkaline sequences would be a position of ductility contrast in the Shoal Lake area which could localize strain. An early laterally extensive fault, possibly related to the Crowduck Group sediments (Figure 054.1), may serve as a zone of weakness for the development of the Crowduck Lake-Witch Bay Shear Zone. Later sub-vertical movement along the Crowduck Lake-Witch Bay Shear Zone has modified the fabrics related to the earlier events.

Smith (1986) concluded that gold deposition in the Shoal Lake Deformation Zone was coincident with the waning stages of the intrusion of the Snowshoe Bay Batholith. It is possible that gold mineralization within the Crowduck Lake-Witch Bay Shear Zone is contemporaneous with the emplacement of the Canoe Lake Stock and the dextral shearing event along the shear zone; however, any evidence of such a connection is masked by later alteration and deformation.

DISCUSSION AND SUMMARY

An intimate relationship between the Canoe Lake Stock and gold mineralization in the Bag Bay-Helldiver Bay area is strongly suggested. Similar relationships have been noted in the vicinity of the High Lake Stock (Colvine and Sutherland 1979; Pedora 1976; Davies *et al.* 1985) and the Snowshoe Bay Batholith (Smith 1986). A similar spatial relationship is also present for gold occurrences on the southern flank of the Dryberry Batholith, east of Kenora. Several authors have noted porphyry-type mineralization within these intrusions (Campbell 1973; Davies 1965, 1978). Pedora (1979) noted metal zonation surrounding the southern phase of the High Lake Stock. An apparent metal zonation is also evident on the southwestern flank of the Canoe Lake Stock.

Chalcopyrite, molybdenite, galena, and bismuthinite are found in occurrences proximal to the stock, while arsenopyrite is more common away from the stock. This apparent metal zonation, combined with temporal and spatial evidence, strongly points to a genetic link between stock emplacement and gold mineralization.

The relationship of the Canoe Lake Stock to gold occurrences hosted within the high-strain zones described herein is less than clear. The only relationship identified to date between the stock and the occurrences is spatial. It is possible that continued deformation after gold deposition has masked any textural evidence related to the mineralizing event. The preponderance of gold occurrences south of the Canoe Lake Stock, rather than to the north, may be a function of the host lithologies in those areas. It is most likely that the lower mafic sequence, exposed south of the Canoe Lake Stock, is a preferred host to gold-bearing fluid as suggested by previous workers (Colvine and Sutherland 1979, Davies and Smith 1984). It is interesting to note that the Mikado Mine is in a very similar position in the stratigraphy to that of the Duport Mine, on the western limb of the Gull Bay-Bag Bay Anticline (Smith 1986).

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055. The Occurrence of Gold in the Cameron-Rowan Lakes Area: Preliminary Report on the Monte Cristo and Victor Island Gold Prospects in the Monte Cristo Shear Zone

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

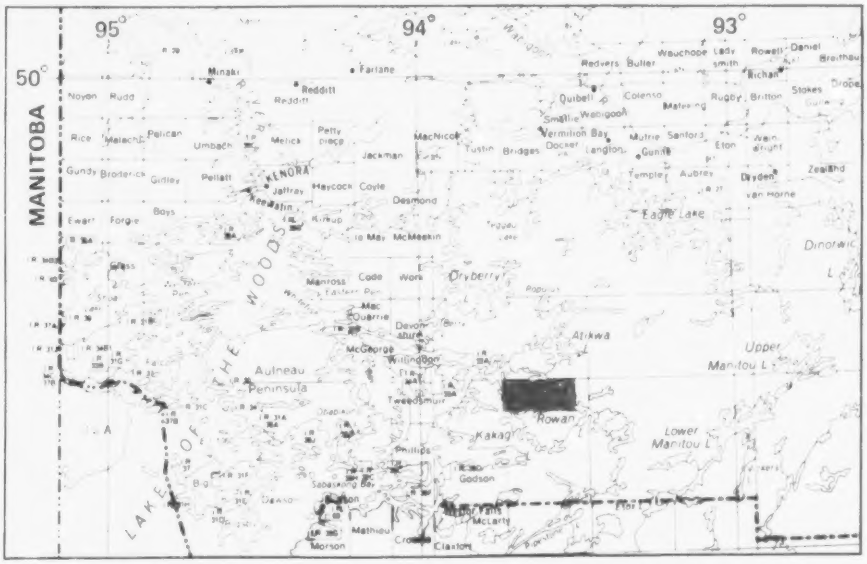
The Cameron-Rowan Lakes area is located in the Kenora Mining District about 80km southeast of Kenora (Latitude 49°17'N, Longitude 94°44'W, Location Map). The area has been subject to extensive claim staking and exploration (The Northern Miner 1983a, 1983b) since the discovery in 1983 of the Cameron Lake Gold Deposit by Nuinsco Resources Limited.

Detailed field-based studies at Cameron Lake have characterized the alteration, geochemistry, and structural control of the deposit (Melling and Watkinson 1985, Melling *et al.* 1985; 1986). Regional geological investigations in the area include lithostratigraphic mapping (Melling and Watkinson, in press), volcanic facies modeling (Johns, this volume) and metallogenetic studies (Buck, this volume). This summary presents the preliminary results of detailed observations of the Monte Cristo and Victor Island Gold Prospects in south-central Rowan Lake (Figure 055.1), based on field work during 1986 and on the results of previous work. It represents a contribution to the continuing program of the Mineral Deposits Section to document the geology of Ontario's gold deposits and thereby develop a model for their origin (Colvine *et al.* 1984).

GENERAL GEOLOGY

The Cameron-Rowan Lakes area lies at the western extremity of the Archean, Savant Lake-Crow Lake Metavolcanic-metasedimentary Belt (Trowell *et al.* 1980) in the Wabigoon Subprovince of the Canadian Shield. The eastern end of Rowan Lake was mapped by Thomson (1936), and more recently Kaye (1973) mapped a larger area encompassing both Cameron and Rowan Lakes.

The Cameron-Rowan Lakes area is located within an arcuate belt of metavolcanic rocks to the northeast of the southeast-striking, northeast-dipping Pipestone-Cameron Fault (Figure 055.1). The structural geology of the area is dominated by the Shingwak Lake Anticline. The axial surface of the fold has an east-northeast strike and the plunge is steep toward the west-southwest (Kaye 1973). The anticline is asymmetric, with a southeast vergence. The Rowan Lake Volcanics, a thick, predominantly pillowed, subaqueous basaltic flow succession, are exposed in the core of the anticline. These rocks are overlain by the Cameron Lake Volcanics, a mixed succession of south-facing, subaqueous, pillowed and massive basaltic rocks, and intermediate to felsic volcaniclastic rocks.



LOCATION MAP

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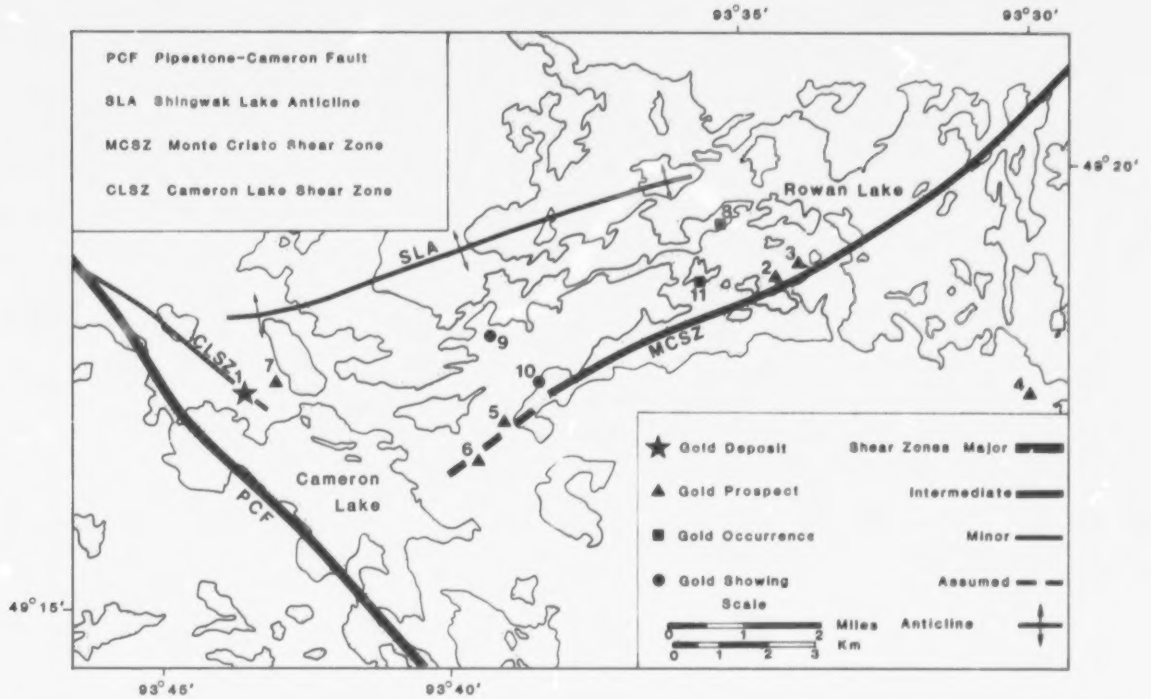
93°35'
93°30'
PCF Pipestone-Cameron Fault
SLA Shingwak Lake Anticline
MCSZ Monte Cristo Shear Zone
CLSZ Cameron Lake Shear Zone
49°20'
Rowan Lake
SLA
MCSZ
CLSZ
PCF
Cameron Lake
1
2
3
4
5
6
7
8
9
10
11
Gold Deposit
Gold Prospect
Gold Occurrence
Gold Showing
Shear Zones Major
Intermediate
Minor
Assumed
Anticline
Scale
Miles
Km
0
1
2
3
49°15'
93°45'
93°40'

Figure 055.1. Major structural elements of the Cameron-Rowan Lakes area and their relationship to the distribution of gold mineralization. (1) Cameron Lake Deposit, (2) Victor Island Prospect, (3) Monte Cristo Prospect, (4) Wampum Lake Prospect, (5) Sullivan Prospect, (6) Meston Prospect, (7) Beggs Lake Prospect, (8) Patmore Occurrence. (9) Roy showing, (10) Kurylіw-Sullivan Bay showing, (11) Unnamed Showing. Sources: Archibald (1982, 1985), Blackburn and Janes (1983), Burden (1986), de Quadros (1986), and Jones (1985).

Gabbroic sills were emplaced at all levels in the succession before folding. Felsic porphyry sills and dikes, and quartz monzonite stocks, intrude all of the older strata. The Cameron Lake Volcanics were intruded by the Nolan Lake Stock in the southeastern corner of the Cameron-Rowan Lakes area. All rocks have been metamorphosed to greenschist facies assemblages.

GOLD MINERALIZATION IN THE CAMERON ROWAN LAKES AREA

The distribution of gold in the Cameron-Rowan Lakes area, and its relationship to major structural elements, are illustrated in Figure 055.1. Where available data allow, gold concentrations have been classified as deposits (>100 000 ounces proven reserves), prospects (some underground development or >2000 feet of diamond-drilling and trenching), occurrences (limited exploration, which may include diamond-drilling and trenching), and showings (significant assays but little exploration).

The Cameron Lake Deposit (Number 1, Figure 055.1), the most significant gold mineralization discovered to date in the area, has drill-delineated reserves of 1 625 202 short tons grading 0.16 ounce gold per ton (Melling *et al.* 1986). The deposit remains open to the east and at depth. Gold occurs in and around a system of pyritic breccia veins, which are enveloped by an ankerite-sericite-rich alteration halo. Auriferous zones are confined to a shear zone (the Cameron Lake Shear Zone) that transects mafic metavolcanic rocks.

Several gold prospects are associated with the Monte Cristo Shear Zone (Figure 055.1). These include the Monte Cristo and Victor Island Zones, being explored by Nuinsco Resources Limited, and the Sullivan and Merton Zones, being explored by New Canolan Resources. The latter two prospects are associated with quartz-carbonate veining in east-northeast-trending zones of carbonatized chloritic schists; gold occurs with pyrite (Beard and Garratt 1974; Archibald 1982).

Other anomalous gold concentrations in the area under current investigation include (Figure 055.1): the Wampum Lake Prospect (Corporation Falconbridge Copper), the Patmore Occurrence and the Roy showing (Bigstone Minerals Limited), the Beggs Lake Prospect and the Kurylіw-Sullivan Bay showing (Nuinsco Resources Limited), and several unnamed occurrences (Silver Lake Resources Incorporated). Grades in excess of 0.10 ounce gold per ton have been reported from most of these showings.

These localities are characterized by the following features:

1. zones of high strain

2. quartz-carbonate veins, with associated pyrite (locally breccia veins)
3. carbonate-sericite-quartz±pyrite wallrock alteration
4. proximity to gabbro-volcanic rock contacts
5. location within the Cameron Lake Volcanics, or very close to their lower contact

THE MONTE CRISTO SHEAR ZONE

The southwest-trending, north-dipping Monte Cristo Shear Zone (MCSZ) has been traced 9 km from the northeastern shore of Rowan Lake into Sullivan Bay where it is believed to continue a considerable distance beneath the water (Figure 055.1). In the central part of Rowan Lake, the shear zone varies from 125 m (410 feet) to 250 m (820 feet) in width. Exposures of the deformed rocks which collectively define the MCSZ, occur on several islands and peninsulas within the lake.

Bedding in the least deformed mafic volcanic and intermediate volcaniclastic rocks outside the MCSZ averages 250°/86°N (Figure 055.2.A). Reliable top indicators (graded beds, dewatering structures, well formed pillows) consistently show younging to the south, indicating an overturned succession. The rocks display two cleavages: an early, prominent, regionally developed foliation which is oriented 268°/86°N (Figure 055.2.B) and a later, weak foliation oriented 119°/73°N. One small scale fold closure was observed whose axial surface trace is oriented 278°/76°N with its hinge line plunging 62°E/082° (Figure 055.3). These trends are similar to those inferred for the Shingwak Lake Anticline (Figure 055.1).

The state of strain in the least deformed rocks outside, and to the north of the MCSZ, was determined by using shapes of pillows and lapilli. Within horizontal sections, aspect ratios are small (<5:1). Where vertical rock faces are available, aspect ratios are large (>9:1), with steeply plunging long axes. This relationship approximates a prolate ellipsoid and suggests a significant component of regional, vertical extension. The state of strain increases in close proximity to the shear zone boundaries. Aspect ratios in horizontal sections are higher (>12:1) and flattening occurs subparallel to the shear zone boundaries.

The MCSZ is a long, subconcordant structure which trends 240°/80°N (Figure 055.1). It is defined as a zone of high strain by its crosscutting nature and the presence of strongly foliated, compositionally banded (millimetre to centimetre scale), chlorite-sericite-quartz+carbonate schists (Figure 055.4). The mean foliation (shear foliation) measured in the MCSZ is 246°/83°N (Figure 055.2.C). Within the shear zone bedding was not recognized; primary textures and structures are either indeterminate or transposed into the shear foliation. Due to the paucity of outcrop, and poor or incomplete boundary exposures, it was not possible to trace bedding or foliation into the shear zone; however, since the width of the MCSZ (up to 250 m) far exceeds that of any individual bedding unit recognized to date, it may be inferred that several rock types are present within the high strain zone.

A steeply plunging, east-trending mineral lineation, oriented 80°E/090°, occurs in the strongly foliated rocks (Figure 055.2.D). It is interpreted as a stretching lineation because of pull-apart structures which occur down plunge. The orientation of the stretching lineation is interpreted as indicating the direction of transport associated with the component of simple shear. Thus, a dip-slip transport direction is implied for the rocks in their present position.

Unique to the MCSZ, but not ubiquitous, are asymmetric, steeply plunging, east-trending S-folds of the shear foliation (Figure 055.4). The folding is widespread, but is most pronounced and tightest near the shear zone boundaries. Fold style varies considerably from open to tight. The scale of folding ranges from several centimetres to about 1 m for the short limbs, and axial surface traces are generally not continuous over more than a few metres. There is a consistent orientation of axial planes oblique to the shear foliation (274°/84°N; Figure 055.2.E) and coeval axial planar crenulation cleavage. Hinge line plunge orientations average 78°E/074° (Figure 055.2.F) but are, in general, shallower in the west (about 70°) and steeper in the east (about 85°). Locally, the limbs of the tightest folds are apparently "sheared off", trapping the fold hinges.

Conjugate kink bands are locally developed within the strongly foliated rocks of the MCSZ near the shear zone boundaries. Axial surfaces trend 180° and 120° for the Z- and S-type flexures, respectively, and both dip subvertically.

On the southern limb of the MCSZ, there is evidence for the existence of a brittle fault. Horizontal slickensides are developed on chloritic surfaces that overprint the stretching lineation in two localities (Wade 1985) and drillholes commonly intersect a narrow (<1 m) zone of fault gouge which separates the deformed rocks of the MCSZ from those rocks to the south of the structure. The sense of displacement could not be resolved due to a lack of crosscutting markers or other suitable indicators.

In order to evaluate the sense of shear displacement on the MCSZ, Wade (1985) carried out a structural study which included thin section analysis. Microtextures of kinematic significance observed in specimens from the MCSZ include: flattened grains, displaying both symmetric and asymmetric pressure fringes; pull-apart structures; microfolds; inclined fabrics; and displaced grains (microfaults). Since the majority of natural shear systems involve both pure and simple shear, the reliability of rotated structures is suspect (Gosh and Ramberg 1976; Hamner 1984). Accordingly, emphasis was placed on inclined fabrics and displaced grains.

The results of Wade's (1985) study suggest that when looking east at a vertical section through the MCSZ the overall sense of shear is sinistral. This indicates that the south side moved "up" relative to the north side, in a direction parallel to the lineation.

THE MONTE CRISTO GOLD PROSPECT

The Monte Cristo Gold Prospect is located along the shoreline of a prominent peninsula in south-central Rowan Lake (Figure 055.1). It was originally discov-

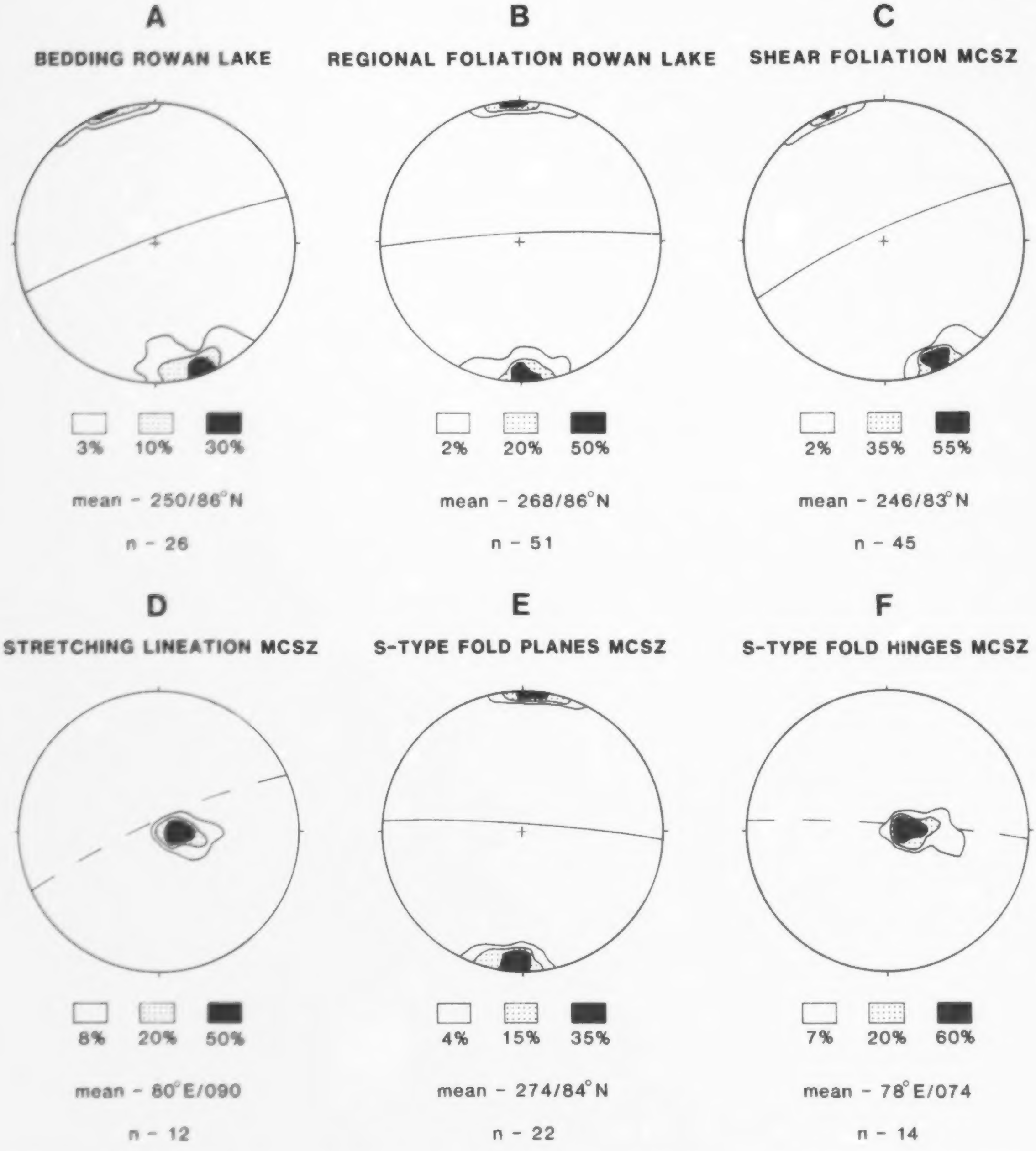

Figure 055.2. *Contoured, lower hemisphere equal area stereographic projections of structural data from Rowan Lake and the Monte Cristo Shear Zone. (A) Poles to bedding, Rowan Lake; great circle represents the mean bedding plane. (B) Poles to regional foliation, Rowan Lake; great circle represents the mean foliation plane. (C) Poles to shear foliation, MCSZ; great circle represents the mean shear foliation plane. (D) Stretching lineation, MCSZ; dashed great circle represents the mean shear foliation plane. (E) Poles to axial planes of S-folds of the shear foliation, MCSZ; great circle represents the mean axial plane. (D) Fold hinges of S-folds MCSZ; oashed great cricle represents the mean axial plane.*

73
119
278
76
278

Figure 055.3. *Small scale fold closure which illustrates the relationships between bedding, cleavages, and fold orientation. The light coloured rock is felsic lapilli tuff (stippled in sketch). The dark coloured rock is mafic lapilli tuff which contains some felsic fragments. The contact between rock types is marked by a thin (1 cm) seam of tourmaline. Located on a small island 1 km northwest of the Victor Island Prospect.*

ered in 1899, when 6 trenches and 2 shafts of 4 m (13 feet) and 6.7 m (22 feet) were excavated. In 1937, 8 diamond-drill holes were completed (Jones 1985).

The composite gold-bearing zone defined to date has an average strike length of about 73 m (250 feet) and a average width of about 10 m (33 feet). It roughly parallels the MCSZ and is apparently longer near surface than at depth. The gold zone dips approximately 85° north-northwest, plunges almost vertically, and has been traced to a depth of 183 m (600 feet) (Figure 055.5).

Rather than consisting of one continuous zone of gold mineralization, the Monte Cristo Prospect is made up of several shoots or pods which are discontinuous in cross section. The best gold grades occur within quartz carbonate-albite+tourmaline+fuchsite veins associated with pyrite. The veins are up to several metres wide and locally contain angular, foliated, pervasively altered rock fragments. The veins may be highly contorted or dismembered. Locally, isolated patches of vein minerals are completely enveloped by pervasively altered, strongly foliated rocks. Alteration assemblages in the pervasively altered, gold-bearing, mafic volcanic host rocks consist of iron carbonate-sericite-quartz-albite-pyrite+fuchsite+tourmaline. Minor chalcopyrite, pyrrhotite, and rutile and rare molybdenite are also present. Pyrite, up to 10 percent (commonly 2 to 5 percent), is sieve textured and contains numerous inclusions of silicate, carbonate, sulphide, and oxide minerals. Gold occurs as inclusions in pyrite grains, as coating on pyrite grains, along annealed grain boundaries in pyrite aggregates, and as free gold in the silicate/carbonate gangue. Gold is most closely associated with pyrite. Some of the better results were found in diamond-drill holes NM-1 and NM-22, where grades are 0.170 ounce gold per ton over 13.3 m (43.5 feet), and 0.134 ounce gold per ton over 15.1 m (49.6 feet), respectively (Jones 1985).

The alteration zone is symmetrical and grades into least altered chlorite-sericite schists of the MCSZ in both the hanging wall and foot wall of the Monte Cristo Zone. A gabbroic sill, 70 m (230 feet) thick, is located in the least deformed rocks about 140 m (400 feet) into the footwall near the southern boundary of the MCSZ.

THE VICTOR ISLAND GOLD PROSPECT

The Victor Island Gold Prospect is situated within the MCSZ about 900 m (3000 feet) west-southwest of the Monte Cristo Prospect (Figure 055.1). It is poorly exposed in outcrops on the northern shore of Victor Island. Gold showings were originally discovered in 1899 and a shaft was sunk to a depth of not less than 7.6 m (25 feet). One diamond-drill hole is recorded to have been drilled in 1937 (Jones 1985).

The gold zone defined, to date, has an average strike length of about 61 m (200 feet) and an average thickness of about 6.5 m (20 feet). It has been traced from a blasted trench at surface to a depth of approximately 213 m (900 feet). The gold zone plunges at about 70° to the east-northeast and dips 87° west-northwest (Figure 055.6).

The main zone of gold enrichment in the Victor Zone is a steeply plunging, cigar-shaped zone of silicification and/or veining. Locally brecciated fragments of the host rocks are included within veins; however, in general these rocks are siliceous, medium grey, and of indeterminate massive textures. The enveloping alteration assemblage is similar to that at the Monte Cristo Prospect and gold has similar modes of occurrence. The highest grade to date is 0.270 ounce gold per ton over 13 m (42.6 feet), from bore hole NM-25.

Unlike the Monte Cristo Prospect, the gold zone at the Victor Prospect is not symmetrical. In the hanging wall, least altered chlorite-sericite schists of the MCSZ grade into pervasively altered, gold-bearing rocks; however, to the south, in the foot wall the auriferous zone is truncated by a brittle fault. The fault is characterized by up to 2 m (7 feet) of fracturing and brecciation including local chloritic gouge. Locally, fragments of pervasively altered, gold-bearing rock occur within the gouge. Commonly, pyrite is

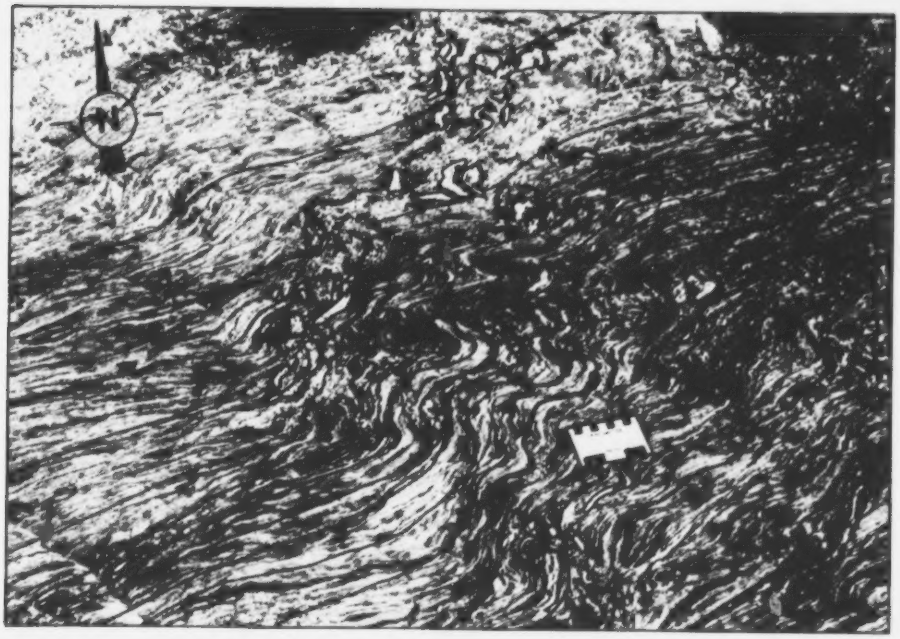

Figure 055.4. Strongly foliated, S-folded, chlorite-sericite-quartz schist of the Monte Cristo Shear Zone. The shear foliation is defined by compositional layering and parallel mineral alignment. Note the S-folds of the shear foliation and the dismembered quartz pods.

increasingly fractured with proximity to the southern boundary of the Victor Zone.

STRUCTURAL CONTROL

Prior to 1986 it was recognized that the geometries of the Monte Cristo and Victor Gold Zones were influenced by deformation processes within the MCSZ; however, the relative timing of deformation and gold mineralization was unknown. The consistency of orientation between S-folds of the shear foliation and the geometry of the gold zones is not fortuitous, but whether deformation within the MCSZ significantly modified the geometry of early gold zones, or alternatively, whether gold mineralization occurred late in the structural development of the MCSZ and the fluids were channeled through dilatant fold hinges, remained equivocal.

In order to evaluate these hypotheses, detailed field mapping of deformed exposures of the MCSZ was initiated, with emphasis placed on identifying small scale zones of alteration and interpreting their relationship to deformation. Two types of alteration zones were identified at the outcrop scale: a) tabular layers of boudinaged carbonate-rich alteration, and b) zones of S-folded and dismembered carbonate-rich pods.

The tabular, boudinaged, carbonate-rich type of alteration was observed about 1 km east-northeast of the Monte Cristo Prospect (Figure 055.7). It consists of a discrete layer, more than 2 m long and 15 cm thick, of pervasive carbonatization, which occurs within the chlorite-sericite-quartz schists of the MCSZ. The rocks weather recessively and have a distinctive bright reddish rusty colour. Thin chloritic seams and folia of the host schists occur locally within the altered layer. Contacts between this carbonate-rich type of alteration and the host schists are always sharp.

The tabular layer occurs at a low angle to the shear foliation, strikes 233°, and dips steeply to the north. The layer pinches and swells along strike and is locally dismembered, with up to 0.6 m between individual boudins. The altered rocks are cut by several quartz-tourmaline veins which strike about 345° and dip steeply to the east and west (Figure 055.7).

The second type of alteration was observed about 1 km west of the Victor Prospect (Figure 055.8). It consists of a zone, more than 6 m long and 2 m wide, of dismembered, S-folded, carbonate-rich pods which occur within the chlorite-sericite-quartz schists of the MCSZ. The folded pods weather recessively and have a distinctive bright reddish rusty colour. Thin chloritic seams and folia of of the host schists occur locally within the altered pods. Contacts between the pervasively altered carbonate-rich pods and the host rocks are always sharp.

The size of individual pods within the zone varies from centimetre to metre scale. The zone is subparallel to the shear foliation. Larger pods are commonly cut by small quartz-tourmaline tension veins oriented 177°/75° west. The folded, dismembered pods display an S-type fold asymmetry. Hinge lines plunge about 60°/075° and axial planes are oriented 265°/75° north (Figure 055.8).

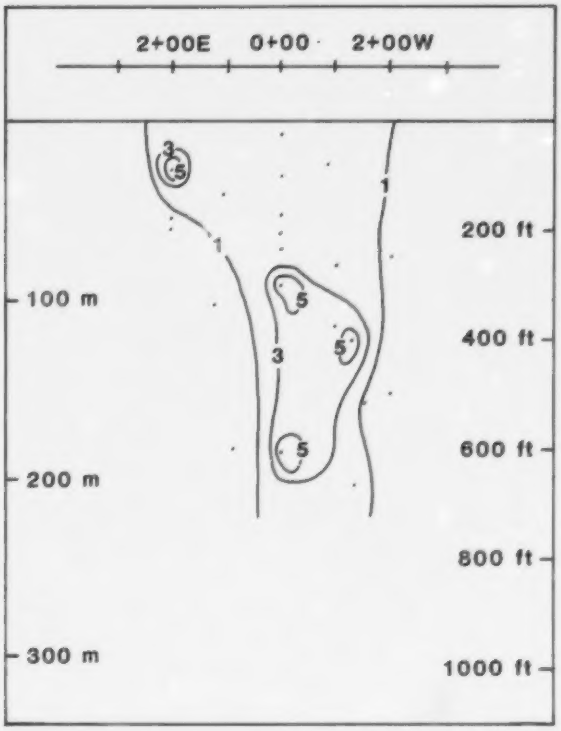

Figure 055.5 *A longitudinal section of the Monte Cristo Gold Zone, dipping 85°N within the plane of the Monte Cristo Shear Zone. Contours represent the value of gold grade (in ounce per ton) times the thickness (feet). Drillhole piercing points are represented by dots. Note the subvertical pitch of the composite gold zone. This section is looking south (modified after Jones (1985)).*

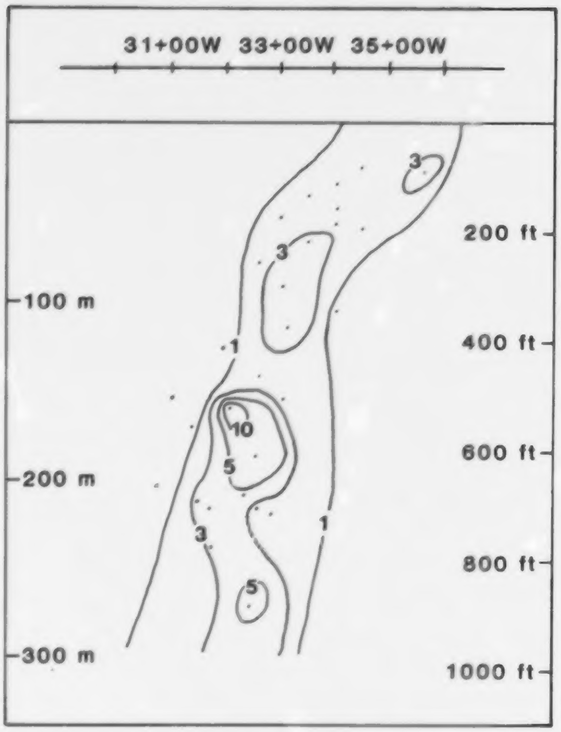

Figure 055.6 *A longitudinal section of the Victor Island Gold Zone, dipping 85°N within the plane of the Monte Cristo Shear Zone. Contours represent the the value of gold grade (oz/ton) times the thickness (feet). Drill hole piercing points are represented by dots. Note the 70°E pitch of the gold zone. This section is looking south (modified after Jones (1985)).*

DISCUSSION

The following features are relevant to the interpretation of the structural control and relative timing of gold mineralization within the MCSZ:

1. The MCSZ is a slightly discordant structure in which primary features (bedding, rock textures) are indeterminate.
2. Fault rocks within the MCSZ display a strong chlorite-sericite-quartz compositional layering, interpreted as a shear foliation.
3. The dominant lineation observed in rocks from the MCSZ is interpreted as a stretching lineation, which coupled with thin section analysis, indicates reverse, slightly oblique, dip slip movement for the rocks in their present position.
4. S-folds and coeval crenulation cleavage of the shear foliation are interpreted as having developed late in the structural evolution of the MCSZ.
5. Foliation within the least deformed rocks outside the MCSZ has a similar orientation to S-fold axial planes and crenulation cleavage of the shear foliation within the MCSZ (Figures 055.2.B and 055.2.E).
6. The Monte Cristo Gold Zone consists of discontinuous gold shoots which collectively define a long, vertically plunging gold zone (Figure 055.5).
7. The Victor Island Gold Zone is a long cigar-shaped body which plunges steeply toward the east (Figure 055.6).
8. The tabular, boudinaged carbonate-rich type of alteration observed on surface is subparallel to the shear foliation within the enveloping MCSZ (Figure 055.7).
9. The zone of S-folded and dismembered carbonate-rich pods, observed on surface, is subparallel to the shear foliation in the enveloping MCSZ (Figure 055.8).
10. The contacts between both types of alteration observed on surface and their deformed host rocks, are sharp and interpreted as tectonic.
11. Both types of alteration on surface are similar to those observed in diamond-drill core from the Victor Island and Monte Cristo Gold Prospects.

Collectively, these features indicate an intimate relationship between deformation within the MCSZ

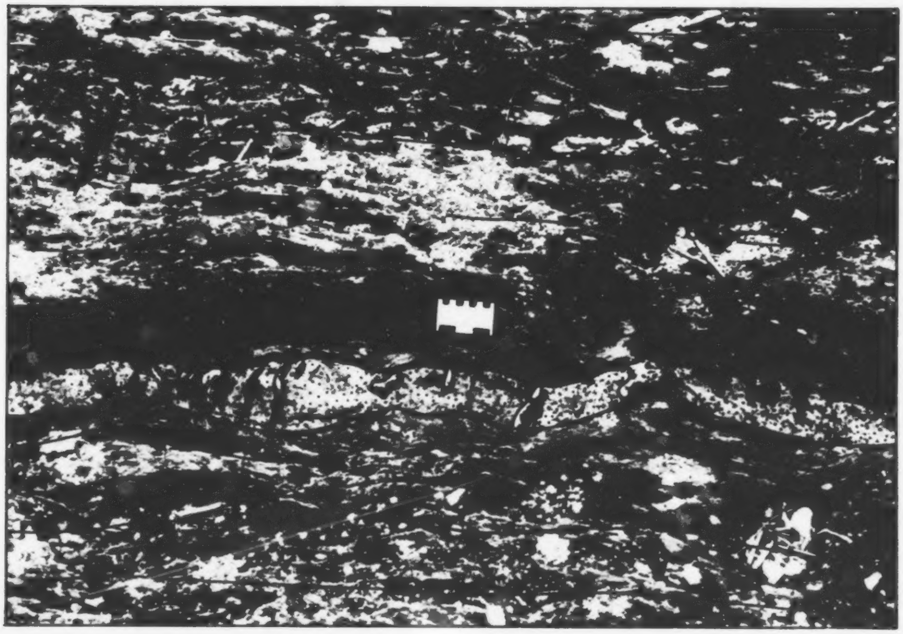

Figure 055.7. *Tabular, boudinaged carbonate-rich type of alteration within strongly foliated rocks of the Monte Cristo Shear Zone. Note the pinch and swell of the layer and the crosscutting, steeply dipping, quartz-tourmaline tension veins. The altered layer is slightly discordant to the shear foliation.*

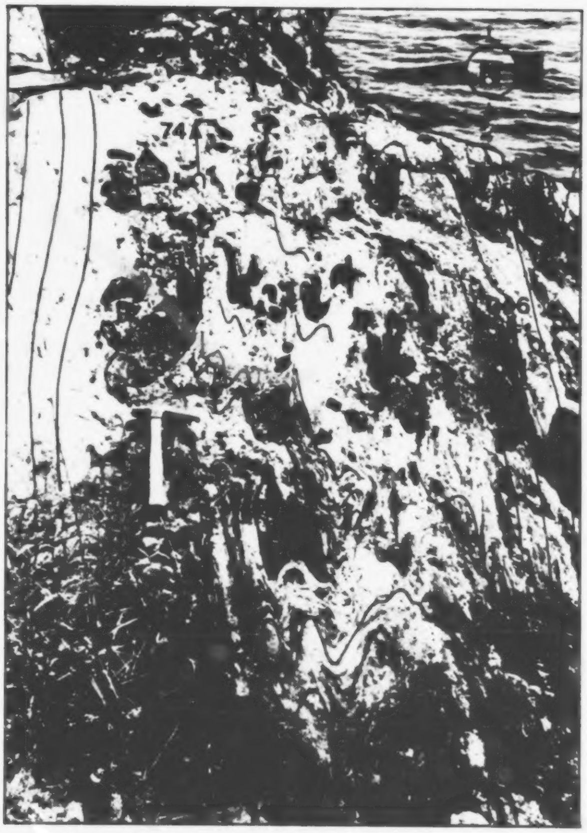

Figure 055.8. *Dismembered, S-folded, carbonate-rich pods within strongly foliated rocks of the Monte Cristo Shear Zone. Dismembered pods occur within a discrete zone of intense folding. Note the orientation of the folded pods.*

and the orientation of contained gold zones. The Victor Island Zone plunges approximately 70° east (Figure 055.6), which is similar to the orientation of S-folds observed nearby on surface. The Monte Cristo Zone plunges vertically (Figure 055.5), which is again similar to the orientation of S-folds measured nearby on surface.

The two types of alteration zones observed on surface are essentially small scale "gold zones" analogous to the larger gold zones identified by diamond drilling. Both types of alteration zone have been deformed during the S-folding event, as indicated by their tectonic contacts, crosscutting tensional veins, pinch and swell structures, dismemberment, and folding. The Monte Cristo Zone is typified by the dismembered, S-folded, carbonate-rich pods observed on surface (Figure 055.8) whereas the Victor Island Zone is more akin to the tabular, boudinaged, carbonate-rich type of alteration (Figure 055.7). The structural control manifests itself in the reorientation of gold zone morphology rather than dilatency within fold hinges.

The specific timing of alteration and gold deposition with respect to earlier vertical movement on the MCSZ is as yet unknown; however, the presence of chloritic seams and folia within the altered pods on surface suggests early syntectonic gold-bearing fluid migration. Further structural analysis, detailed petrography, X-ray diffraction analysis, and geochemistry are underway to assist in the complete documentation of the alteration and structural control associated with gold prospects in the Cameron-Rowan Lakes area, and to provide insight into the processes of gold concentration.

ACKNOWLEDGMENTS

Grateful appreciation is extended to the staff of Nuinsco Resources Limited for providing unrestricted access to data on their properties in the Cameron-

Rowan Lakes area. Appreciation is also extended to New Canolan Resources Limited, Silver Lake Resources Incorporated, and Bigstone Minerals Limited, for providing access to their properties and data that they have compiled while conducting exploration programs in the Cameron-Rowan Lakes area.

Thanks are also expressed to A.C. Colvine, A.D. Hunter, P.L. Jones, M.R. Murrell, K.H. Poulsen, and D.H. Watkinson, for visiting the field area, engaging in discussion, and contributing their ideas on the processes of deformation and gold mineralization. M.D. McNicoll was a keen and conscientious field assistant.

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056. Metallogenetic Studies in the Kagagi-Rowan Lakes Area, District of Kenora

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

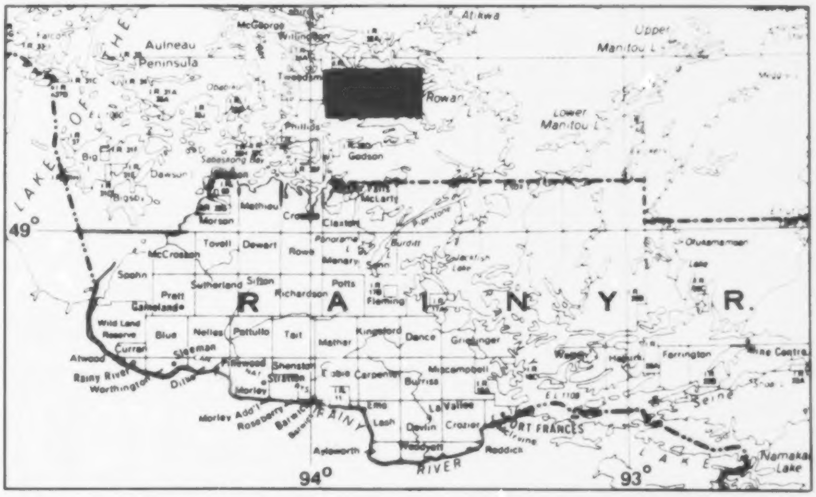
This report summarizes observations made during the preliminary stage of a three-year project initiated to investigate controls on gold mineralization in the Kakagi-Rowan Lakes area of northwestern Ontario (Location Map). The Kakagi-Rowan Lakes area, one of the principal gold-bearing areas of northwestern Ontario (Blackburn and Janes 1983), has a long history of gold exploration (Beard and Garratt 1976). Interest has been recently renewed by the discovery in 1983 of the Cameron Lake Deposit by Nuinsco Resources Limited. Present reserves outlined at this property total 1 625 202 short tons grading 0.16 ounce gold per ton (Melling *et al.* 1986). At several other properties, notably in the Flint Lake area, low grade reserves of 50 000 to 100 000 tons have been outlined (Assessment Files, Resident Geologist's Office, Ontario Ministry of Northern Development and Mines, Kenora).

Based primarily on the distribution of gold showings, Blackburn and Janes (1983) suggested three environments for gold mineralization in northwestern Ontario: (i) major lithologic contacts, especially formational contacts in volcanic sequences; (ii) intrusive contacts, both mafic and felsic; and (iii) faults and shear zones. Blackburn and Hailstone (1983) have also pointed out that stratigraphic level may be important in the control of gold mineralization in the Kakagi-Rowan Lakes area, as many of the local gold showings occur near the transition from mafic to felsic or mixed volcanic sequences.

The approach of the present project is to investigate not only the local environments and controls of gold mineralization, but also the regional geology, in order to gain a better understanding of the complete geological setting of gold deposits in the Kakagi-Rowan Lakes area, and thereby identify areas of greater potential for mineralization. Field work during this first year of the program was mainly reconnaissance in nature and concentrated on the Cameron Lake and Flint Lake areas (Figure 056.1). These areas were selected because recent exploration indicated that they would provide the greatest amount of information for the preliminary stage of this project.

REGIONAL GEOLOGY

The regional geology of the study area has been mapped by Kaye (1973), Edwards (1980), and Davies and Morin (1976). A more recent description of the regional geology is provided by Johns (1985). The area is divided by the northwest-trending Pipestone-Cameron Fault. West of this structure the area is underlain by mafic volcanic rocks of the Snake Bay Formation and the overlying intermediate to felsic pyroclastics of the Kakagi Lake Group. The Snake Bay Formation consists of iron-enriched tholeiitic basalts (Blackburn *et al.* 1985). The Kakagi Lake Group is mainly dacitic in composition (Davies and Morin 1976) and calc-alkaline, chemically. Evidence presented by Johns (1985) suggests that the Snake Bay Formation formed in a shallow water environment. Johns (1985) also described deposits in the Kakagi


Aulneau
Peninsula
LAKE OF THE
McGeorge
Willingdon
Tweedsmuir
Atikwa
Upper
Manitou L
Rowan
Lower
Manitou L
Phillips
Big
Dawson
Bigsby
Godson
Mathieu
McLarty
Pipestone L
Morson
Claxton
49°
Tovell
Dewart
Rowe
Panorama L
Burditt
Menary
McCrosson
Senn
Otukamamoan Lake
Sifton
Sutherland
Potts
Richardson
Pratt
Gameland
Fleming
R A I N Y R.
Wild Land Reserve
Blue
Nelles
Pattullo
Tait
Mather
Kingsford
Dance
Griesinger
Ferrington
Curran
Sleeman
Atwood
Rainy River
Worthington
Dilke
Shenston
Pinewood
Morley
Carpenter
Burriss
Miscampbell
Seine
Emo
La Vallee
Morley Add'l
Roseberry
Barwick
RAINY
Lash
Devlin
Crozier
FORT FRANCES
Aylsworth
Woodyatt
Roddick
RIVER
LAKE
Namakan Lake
94°
93°

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

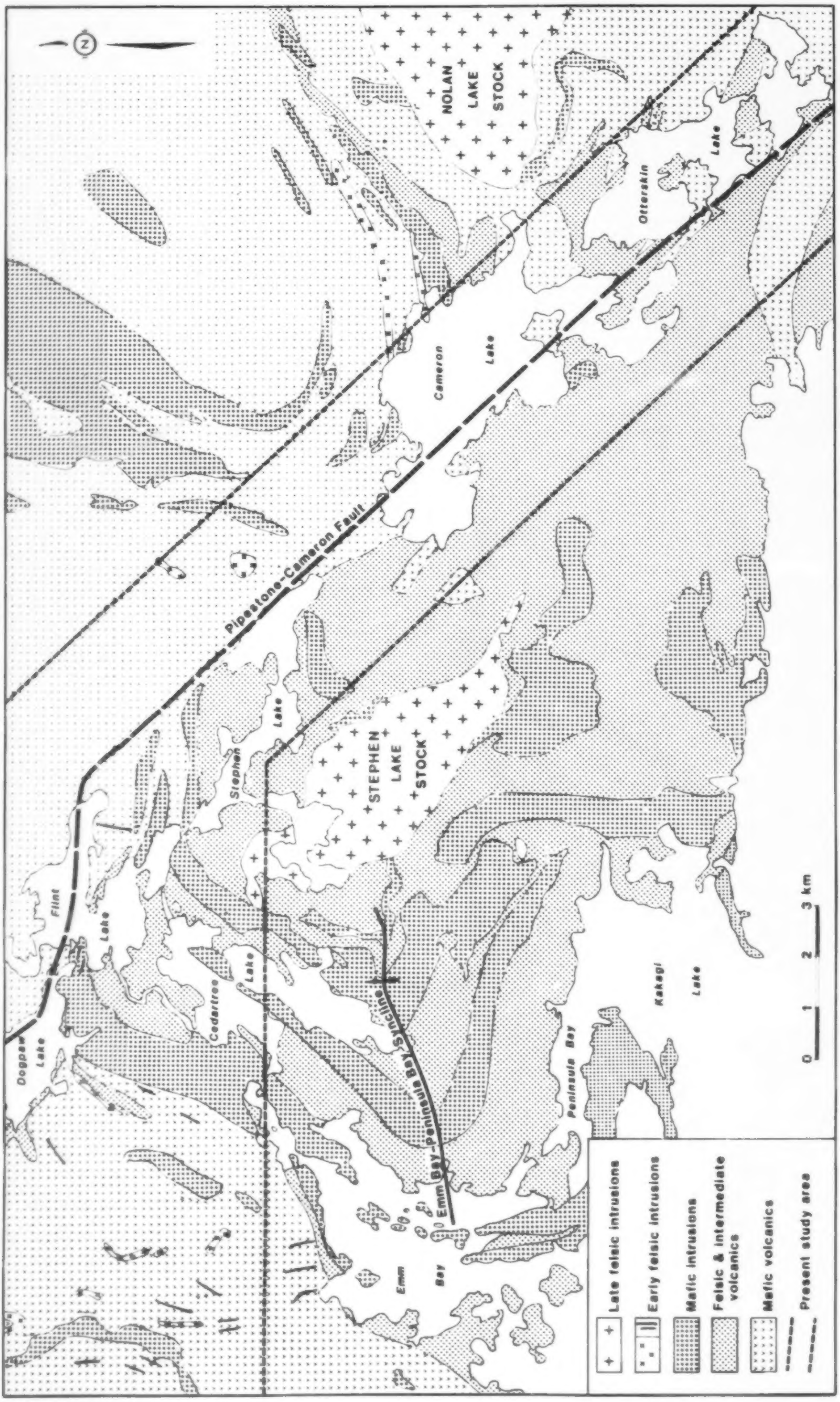

Dogpaw Lake
Flint Lake
Cedartree Lake
Stephen Lake
Cameron Lake
Otterskin Lake
NOLAN LAKE STOCK
STEPHEN LAKE STOCK
Pipestone-Cameron Fault
Emm Bay-Peninsula Bay Syncline
Emm Bay
Peninsula Bay
Kakagi Lake
0 1 2 3 km
Late felsic intrusions
Early felsic intrusions
Mafic intrusions
Felsic & intermediate volcanics
Mafic volcanics
Present study area

Figure 056.1. Regional geology (modified after Kaye 1973; Davies and Morin 1976; Edwards 1980).

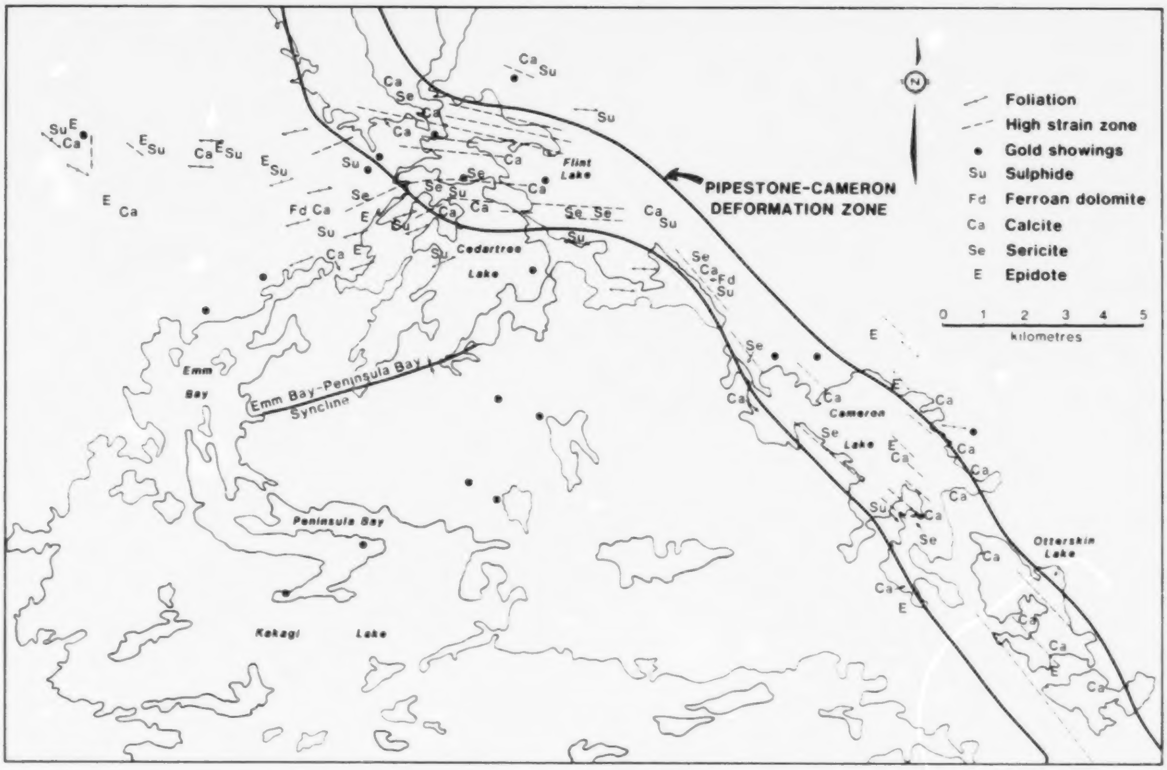


Figure 056.2. Structural geology and alteration patterns.

Lake Group where representatives of proximal, distal, and epiclastic volcanic facies have been interpreted. The northern part of the Kakagi Lake Group has been intruded by the differentiated, peridotitic to gabbroic Kakagi Lake Sills. Early quartz-feldspar porphyry intrusions are common in the area, especially in the Snake Bay Formation west of Flint and Cedartree Lakes (Figure 056.1). Later granitic intrusions are also present, the largest being the Stephen Lake Stock. The southwestern part of the study area has undergone two phases of folding. The first is represented by a north-trending "regional synclinorium" (Osadetz 1979), which was refolded in a second event to produce the Emm Bay-Peninsula Bay Syncline (Figure 056.1).

The area east of the Pipestone-Cameron Fault consists predominantly of mafic flows and intrusions underlying a poorly exposed sequence of intermediate to felsic pyroclastics and tuffs. These units are presently unnamed and have not been correlated with other units of the region (Blackburn *et al.* 1985). Detailed descriptions and facies interpretation for this area have been undertaken by Johns (this volume), and will provide an excellent base for future studies in this area.

STRUCTURAL SETTING

The dominant style of deformation in the area has been the formation of zones of high strain. These zones are defined by the progressive development of a closely spaced foliation and/or extension lineation and are often intensely altered. They are commonly represented in mafic rocks by chloritic schists; in more felsic rocks and pyroclastic units, by quartz-sericite schists. In some cases, due to shearing and alteration, it is impossible to determine the original lithology. In several cases, the foliation in highly strained pyroclastics was represented by tectonic layering formed by elongated fragments and intervening chloritic matrix.

Where these zones contain rotational strain structures, such as rotated veins or phenocrysts, S-C fabrics and shear bands or extensional crenulation cleavage, they are considered to represent simple shear zones, and a sense of displacement could usually be determined. In several cases, evidence of rotation was not observed in zones of high strain and these may represent planes of flattening. Two zones of differing deformation style were recognized in the study area: the Pipestone-Cameron Deformation Zone (PCDZ) and the Emm Bay-Peninsula Bay Syncline (Figure 056.2).

EMM BAY–PENINSULA BAY SYNCLINE

Around and west of Cedartree Lake, the dominant structure is the northern limb of the Emm Bay-Peninsula Bay Syncline. Lithological units in this area are relatively undeformed and trend towards the north at 040° to 050°. An axial planar fabric at 060° to 070° is developed to varying degrees and cuts the stratigraphy throughout the southwestern part of the study area (Figure 056.2). This fabric is defined by a weak, nonpenetrative mineral fabric in finer grained rocks, and by the parallel alignment of long axes of fragments in pyroclastic units. At several locations, especially near the north end of Cedartree Lake, zones of high strain are developed parallel to the axial planar fabric. These zones are defined by a greater intensity of foliation and more schistose rocks. Rotated structures were not observed in these zones. At the northern end of Cedartree Lake, both lithological units and the axial planar fabric rotate towards a series of east-trending shear zones associated with the PCDZ. In this area the axial planar fabric becomes more pronounced and high strain zones more abundant.

PIPESTONE–CAMERON DEFORMATION ZONE

The PCDZ was outlined in the field as a northwest-trending zone of strongly foliated and/or lineated rocks, varying in width from 500 to 3000 m. Within these boundaries the PCDZ is made up of subparallel, discrete zones of high strain, 1 to 50 m in width, alternating with zones of less deformed rock. In general, lithological units within the PCDZ are subparallel to the trend of the deformation zone. Within most of the high strain zones, rotational strain structures were observed, indicating that the PCDZ is the result of a regional scale, simple shear mechanism.

In the Flint Lake area the general trend of the PCDZ changes from northwest to east. In this area several discrete east-trending shear zones were outlined. Subhorizontal extension lineations and rotated structures within these zones indicate that movement was dominantly horizontal with a right handed, or dextral, sense of displacement. However, in at least one location, S-C fabrics and shear bands were observed on a vertical exposure and indicate a north-side-up component of vertical movement. To the west, shear zones in the northern part of Flint Lake gradually return to a northwestern trend. Shear zones in the southern part of Flint Lake rotate gradually to the southwest where they diminish in both width and strain intensity.

In the southeastern part of the study area the trend of the PCDZ remains consistently northwest. Shear fabrics, rotated fragments and lineations in this area indicate that the dominant movement was vertical with a north-side-up sense of displacement. However, at many locations in this area, evidence of horizontal movement was also observed.

STRUCTURAL SUMMARY

The presence of rotational structures in the PCDZ indicates that the deformation has been the result of predominantly simple shear. However, the sense of displacement, indicated by both rotational structures and extension lineations, varies throughout the zone and suggests that the deformational history of the PCDZ has been both complex and variable. The distinct change in trend and predominant horizontal motion observed in the Flint Lake area appears to be related to the presence of the Emm Bay-Peninsula Bay Syncline. The axial planar fabric associated with this fold may have provided an early anisotropy that focused strain development related to later deformation in the PCDZ.

ALTERATION

Epidote represents the earliest alteration in the study area and is found mainly in the mafic volcanic rocks and gabbroic units. Epidote occurs as small (less than 20 cm) pods, vein haloes, and within selvages of pillowed flows. Epidote alteration within high strain zones is commonly deformed by arrays of tension gashes, indicating a more brittle response to deformation than the surrounding rocks. The sense of displacement indicated by the symmetry of the arrays is the same as that indicated by rotated structures within the same high strain zone.

Carbonate is present both as predeformational veins and fracture filling in undeformed rocks, and also as a pervasive syndeformational alteration in the highly strained zones (Figure 056.2). Although calcite is the most common carbonate, ferroan dolomite was observed both accompanying calcite and also as quartz-carbonate veins. At several locations in highly strained zones near Flint Lake and east of Steven Lake, a distinctive pink calcite occurs along foliation planes and also infilling a shear band foliation. Further deformation has caused boudinage and rotation of the calcite infilling. Carbonate is also present in late stage horizontal tensional structures and quartz-carbonate veins throughout the area.

Finely disseminated primary pyrite, chalcopyrite, and pyrrhotite are present in small amounts throughout the Kakagi Lake Sills. Higher percentages of sulphide mineralization were observed in the Flint Lake area and northern Cedartree Lake area whenever the sills were cut by high strain zones. Discontinuous zones of sulphide mineralization associated with carbonate-altered pyroclastics were also seen in the Flint Lake area. In the less deformed rocks outside of the PCDZ, pyrite was often seen in alteration zones near or at the contacts of quartz-feldspar porphyry dikes, isolated shear zones and quartz veins. Quartz-sulphide breccia veins, such as those described for the Cameron Lake Deposit (Melling *et al.* 1986), were not observed during the present project but have been reported in drill core at a showing in the western part of the study area (M. Ogden, Geological Consultant, H.B. O. Engineering Limited, personal communication, 1986).

Sericite and chlorite concentrations are generally restricted to the PCDZ and discrete shear zones outside of that zone, suggesting a syn-shearing formation. At one location on Dogpaw Lake, and at another east of Stephen Lake, sericite schists with a strong hematite staining were observed. In several high strain zones in mafic rocks the original mineralogy has been completely altered to a chlorite-carbonate schist.

GOLD MINERALIZATION

This preliminary project concentrated on examining and interpreting the history of the PCDZ. A brief amount of time was spent in the surrounding areas and at individual gold showings. Because of this, the following represents only a general summary of the regional characteristics of gold mineralization. It is hoped that future studies, especially in areas outside of the PCDZ, will provide a better understanding of gold mineralization throughout the Kakagi-Rowan Lakes area.

Gold showings in the study area can be discussed based on their location inside or outside of the PCDZ. Showings outside of the PCDZ all occur in isolated, discontinuous, sheared, and/or carbonatized zones accompanied by quartz veining. All of the previously known showings outside of the PCDZ, and some promising zones uncovered during recent road work and mapped during the present project, appear to be closely associated with local felsic intrusive rocks. Several showings occur near the contact of one of the Kakagi Lake Sills in a carbonate-rich zone which is also locally intruded by felsic dikes.

Those showings within the PCDZ, including the Cameron Lake Deposit, all occur in wide zones of shearing and carbonate alteration. Host lithologies, where recognizable, include mafic flows, gabbro, felsic pyroclastics, and felsic intrusions. Several of the more promising showings occur in the Flint Lake area where the trend of the PCDZ changes. The only visible gold observed during the present project occurred in quartz veins in an east-trending shear zone north of Flint Lake (Figure 056.2).

At the present time, reported values and outlined reserves are considerably greater for those showings within the PCDZ. Based on limited information gained by the present project, it appears that future exploration for gold in, or closely adjacent to, the PCDZ should concentrate on carbonate-altered shear zones. A more specific target might be the junction of the PCDZ with other regional structures such as represented by the Emm Bay-Peninsula Bay syncline.

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057. Regional Strain State and Alteration Patterns Related to Gold Mineralization in the Uchi-Confederation-Woman Lakes Area

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INTRODUCTION

This was the final field season of a two-year project, initiated to address the nature of, and controls on, gold mineralization in the Uchi-Confederation-Woman Lakes area (*see* location map). The observations described here build upon and expand the results reported previously (Fyon and Lane 1985, 1986). The following regional characteristics of this greenstone belt were addressed: a) structural setting; b) alteration patterns; and c) spatial and temporal relationships between these two features, rock type distribution, and known sites of gold mineralization. The existing geological database (Thurston 1985) provides a foundation, essential for the application of this project. Although the project represents an integrated study, O'Donnell focused primarily on the structural aspects, and Fyon concentrated on the alteration and gold metallogenic features of the area.

This project was made possible through in-year supplementary funding by the Government of Ontario.

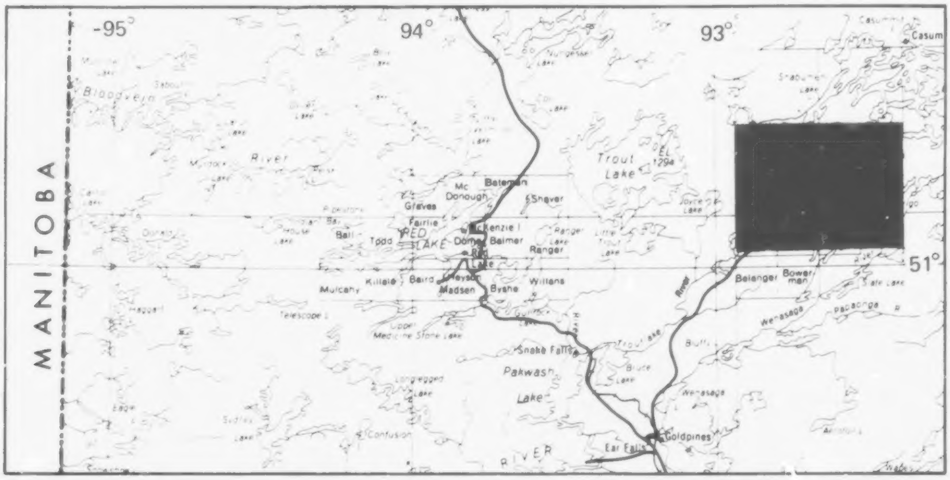
REGIONAL GEOLOGICAL SETTING

Three volcano-sedimentary cycles exist in the area (Pryslak 1971a, 1971b; Thurston 1985). Generally, each cycle consists of a basaltic base, a middle unit of intermediate flows and pyroclastic deposits, and a cap of rhyolitic flows and pyroclastic deposits (Thurston 1985). The lithological units generally have a north strike, and have been folded into a north-trending syncline. The lithological package has been metamorphosed regionally to greenschist or amphibolite grade, and intruded by late felsic dikes and granitoid bodies.

STRAIN STATE

The state of strain was subjectively assessed in the field based on the extent of the development of both a penetrative foliation and lineation. The style and intensity of the deformation is variable, but can be characterized in general by planar zones of intense and often complex fabric development (high strain zones), separated by zones which have experienced much lower levels of strain. The width and spacing of high strain zones and the intensity of the fabric developed varies, both within the zones and in the surrounding rock, but generally increases in the western and southern sections of the area. These highly strained zones formed as a result of varying increments of simple and pure shear. In this report, those highly strained zones which apparently formed primarily in response to simple shear are termed shear zones. The kinematic assessment of the shear zone is based on field observation and is subject to revision, pending microscopic analysis. In some areas, a closely spaced, subparallel array of related shear zones occurs which is referred to as a zone of deformation.

North of Fly Lake (Figure 057.1) shear zones tend to be narrow with sharp boundaries, producing a marked contrast between them and the surrounding, poorly foliated rock. These discrete shear zones are frequently the loci of intense alteration accompanied by quartz and sulphide mineral accumulations of potential economic significance. Toward the south, individual zones of higher strain become less discrete as their width and the foliation intensity in the intervening areas increase. Extension lineations measured in the field include long axes of quartz-feldspar aggregates, strain shadows of rigid inclusions (i.e.


-95°
94°
93°
51°
MANITOBA
Casum
Bloodvein
River
Trout Lake
Mc Donough
Bateman
Shever
Graves
Fairlie
RED LAKE
Todd
Ball
McKenzie I
Dome
Balmer
Ranger
Killala
Baird
Madsen
Mulcahy
Byshe
Willans
Telescope L
Upper Medicine Stone Lake
Snake Falls
Pakwash Lake
Longlegged Lake
Confusion
Ear Falls
Goldpines
RIVER
Belenger
Bowerman
Wenasaga
Papaonga R
Bruce Lake
Slate Lake
Joyce Lake
Little Trout Lake

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

clasts, phenocrysts, porphyroblasts, etc.), stretched clasts, amygdules, varioles and spherules, mica streaks, and long axes of actinolite needles. Foliations measured include preferred orientation of micas (chlorite, white mica, and biotite), and the flattening plane of inclusions, spherules, amygdules, varioles, porphyroblasts/clasts, phenocrysts and clasts.

DEFORMATION SEQUENCE

Observations gathered this summer support the contention of Fyon and Lane (1985, 1986) that this part of the greenstone belt was affected by at least two, and probably more, deformation events. The strongest evidence, that the area has experienced at least two episodes of deformation, can be seen locally by the development of two penetrative foliations which have a crosscutting relationship.

Early Deformation (D_1)

Foliations developed during D_1 are subparallel to stratigraphy, and have a northerly strike and subvertical dip. Extension lineations developed on these surfaces are generally steep. The north-trending strike and subvertical dip of rock units, and the synclinal axial trace through Dent Township, are large scale expressions of this deformation event.

Second Deformation (D_2)

D_2 foliations generally have an easterly trending strike and steep dip. Extension lineations are not generally as steep as those developed during D_1. North of Fly Lake, the strongest manifestation of the D_2 deformation event is a conjugate set of northwest- and northeast-trending shear zones. Of these, the northeast-trending set is more common. To the south of this point, an east-to northeast-trending penetrative foliation is developed.

Subsequent Deformation

Crenulations observed in some of the shear zones overprint D_2 fabrics and indicate either a complicated evolution of the D_2 event or that some areas experienced a subsequent deformation. Along the northern limit of mapping, an east-trending, intensely foliated zone occurs, called the Swain Lake Zone of Deformation (Goodwin 1967). Determinations of kinematic sense within this zone are not straightforward and evidence for conflicting sense was observed at a centimetre scale. Preliminary examination of data suggests that reactivation, but of opposite sense, along surfaces originally developed during D_2 may have taken place in response to compression from a northeasterly direction. Crenulations developed on foliation surfaces at Car and Bathurst Lakes, and extension lineations observed at Grace Lake, are also compatible with the existence of such an event.

CHARACTERISTICS OF DEFORMED AREAS

For purposes of discussion, the area studied has been subdivided on a geographical basis, pending a more refined subdivision into structural domains.

Fly Lake

A major zone of deformation, consisting of a large number of subparallel and anastomosing shear zones, has been traced along the western shore of Fly Lake (Figure 057.1). This zone of deformation has an arcuate trace which follows the western border of a competent, massive quartz and feldspar-phyric flow unit. The foliation within this zone generally trends north and northeast. The dips of foliation surfaces are steep in the north but become moderate in the south. The extension lineation plunges moderately to the northeast. These shear zones have a dextral horizontal component and a northwest-side-down vertical component. Although the extension lineation is moderate, this kinematic sense is consistent with development during D_1, in response to east-west compression.

In the southeastern Fly Lake area, a second, highly strained zone occurs, having a northerly trend. Within this zone, the metamorphic grade is apparently elevated relative to the surrounding less strained rocks. Preliminary kinematic analysis of this zone indicates that a west-side-up component of movement has taken place on moderately dipping, north-trending foliation surfaces. Extension lineations plunge down dip.

Grace Lake

At Grace Lake, bedded metasedimentary units have been folded into an east-to northeast-trending syncline. Foliations measured in this area are also east-trending and steeply dipping. Mineral lineations and long axes of cobbles plunge moderately to steeply west to northwest. Both the foliation and the synclinal axial trace are consistent with a north-south (D_2) compression.

A number of shear zones are also seen at Grace Lake, two of which form a conjugate set consistent with D_2. Crossing the narrows leading to the southwest arm is a northwesterly trending shear zone, which has a dextral horizontal component and a northeast-side-up vertical component. The other member of the conjugate set occurs west of the southwestern end of the lake. This zone trends northeasterly and has the opposite kinematic sense. Other minor shear zones observed in this area define a conjugate set consistent with an east-west (D_1) compression.

Narrow Lake

Several major east-to southeast-trending shear zones define a zone of deformation in this area. The individual shear zones have a steeply dipping foliation and steeply plunging extension lineation. Kinematic analysis of these shear zones is complex. Either more than one kindred of shear zone exists or an early shear zone (D_2) was reactivated during D_3.

Swain Lake

A major high strain zone occurs along the northern shore of Swain Lake. This zone trends east to northeasterly and can be traced along strike to the northern arm of Woman Lake (Figure 061.1). The strain observed in this zone appears to be largely the result

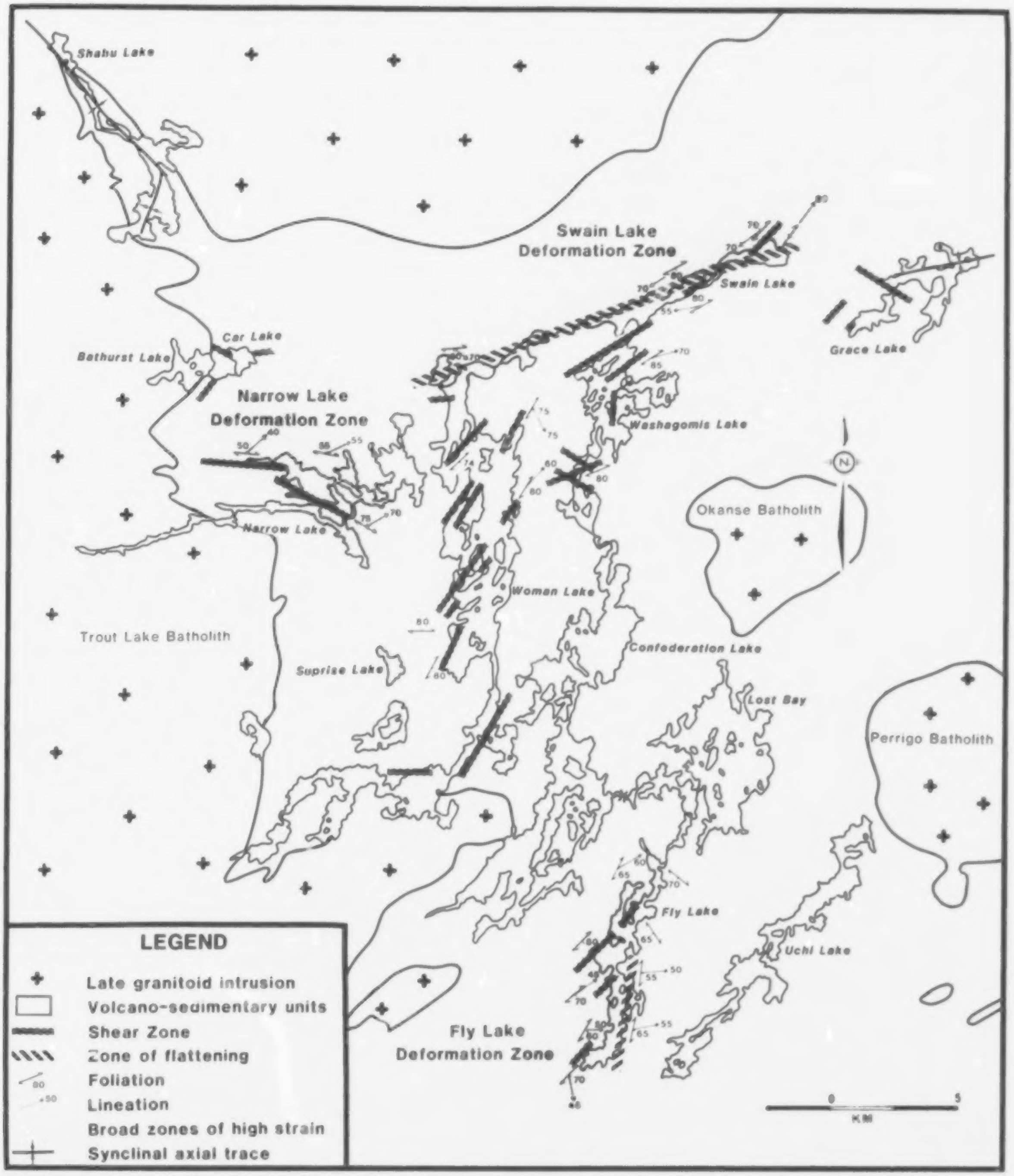

Shahu Lake
Swain Lake
Deformation Zone
Swain Lake
Grace Lake
Car Lake
Bathurst Lake
Narrow Lake
Deformation Zone
Washagomis Lake
Okanse Batholith
Narrow Lake
Woman Lake
Trout Lake Batholith
Confederation Lake
Suprise Lake
Lost Bay
Perrigo Batholith
Fly Lake
Uchi Lake
Fly Lake
Deformation Zone
0
5
KM
LEGEND
Late granitoid intrusion
Volcano-sedimentary units
Shear Zone
Zone of flattening
Foliation
Lineation
Broad zones of high strain
Synclinal axial trace

Figure 057.1. Location of high strain zones in the Confederation-Woman Lakes area identified during the 1986 field season. Shading indicates broader zones of deformation in which a pervasive fabric is developed (Swain Lake) or where a large number of shear zones exist (Narrow Lake, Fly Lake). See the text for preliminary chronological assignment of zones.

of pure shear, and is manifest in a submillimetre-spaced rectiplanar foliation. No consistent fabric asymmetry was observed, but the sense of shear indicated by the fabric is one of north-side-up followed by north-side-down. This implies that the surface has undergone reactivation during either relaxation or a later deformation. A similar fabric relationship was also observed at Narrow Lake.

Bathurst-Car Lakes

Generally, deformation at Bathurst-Car Lakes is manifest in the form of narrow, discrete shear zones which trend east, northeast, and northwest. Kinematics in this area are complex and, at face value, appear inconsistent. Senses indicative of compression from the west, northwest, and northeast are all represented. A crenulation, which is consistent with a northeast compression, commonly overprints the foliation in highly strained zones.

Shabu Lake

The main structure at Shabu Lake appears to be either a complex or refolded fold. A tight syncline with a highly strained (possibly sheared) core trends northwesterly, parallel to the northwestern arm of the lake. A second fold axial trace trends north-northeast, and defines a broad syncline in the southeastern section of the lake.

STRUCTURAL SUMMARY

During the earlier (D_1) deformation event, the major north-trending syncline, axial-planar, northerly trending foliation, and steep extension lineation developed in response to east-west compression.

During the D_2 deformation event, an east-trending foliation, with moderately plunging extension lineation, developed in response to north-south compression. The most persistent expression of the D_2 event is a conjugate shear zone set, having a predominant northeast-trending shear zone array with a moderately northeast-plunging extension lineation, and a sinistral horizontal component. Regionally, the northwest-trending shear zones are not well developed, although locally (Narrow Lake area) they are the better developed set. The Trout Lake Batholith has been affected by this event.

Along the northwestern limit of mapping, reactivation of D_1 and D_2 surfaces may have occurred in response to compression from the northeast. Other evidence for such an event occurs as crenulations developed in foliations at Bathurst and Car Lakes.

REGIONAL METAMORPHISM

The metamorphic grade outside of the zones of deformation, as defined by examination of hand samples, indicates that a change has occurred in the mineralogy and crystallinity of the volcanic rocks, proceeding from north to south and toward the margin of the Trout Lake Batholith. Chlorite, sericite, and biotite, typical of greenschist grade, are stable in the central part of the belt. Rocks immediately adjacent to the Trout Lake Batholith, and at the southern end of Fly and Uchi Lakes, have attained amphibolite grade, consistent with the distribution of metamorphic assemblages reported by Thurston and Breaks (1978).

In the Shabu Lake area, metamorphic grade is generally higher because of the proximity of the bounding granitoid batholiths. Biotite-, hornblende-, and garnet-bearing metasediments are interbedded with calc-silicate rocks at the northwestern end of the lake. Marble, free of calc-silicate minerals, and biotite-bearing, volcaniclastic metasediments, free of garnet, occur at the southern end of Shabu lake.

Two metamorphic isograds are located on Figure 057.2: a) the chlorite-biotite transition; and b) the greenschist/amphibolite isograd, based on the first mesoscopic appearance of hornblende or garnet. The position of the greenschist/amphibolite isograd is not well constrained because of the station density and the uncertainty with which hornblende can be mesoscopically identified in fine-grained volcanic rocks.

In general, the alteration mineralogy within the highly strained zones matches that of the adjacent, less-deformed rocks. However, the mineralogy in two of the shear zones in the Fly Lake area is characterized by an alteration assemblage which may have stabilized at a higher temperature than in the adjacent less deformed rocks.

ALTERATION AND GOLD POTENTIAL OF HIGHLY STRAINED ZONES

To assess the gold potential of a given area, the following criteria have been considered: a) type and intensity of wall rock alteration; b) presence and type of sulphide mineralization; c) historical exploration record; d) lithologies, including the presence and type of intrusive and sedimentary rock; and e) complexity of structural deformation.

FLY LAKE

Alteration

Felsic flows and pyroclastic rocks within a zone of deformation, located along the southwestern shore of Fly Lake (Zone F1; Figure 057.2), have been intensely sericitized and rendered to a quartz-sericite schist. This altered felsic rock lies in an amphibolite grade domain; however, no potassium feldspar, andalusite, sillimanite, or kyanite were observed, although disseminated pyrite is locally abundant.

Sheared intermediate pyroclastic deposits at the southeastern end (Zone F2; Figure 057.2) carry abundant red garnet which coexists with green chlorite (biotite?). While most of the garnet is euhedral, some is extended parallel to the extension lineation, defined by the accompanying chlorite. The northern extent of this garnet-chlorite zone appears to project into the biotite-stable, upper greenschist domain, such that the garnet-bearing assemblage within the shear zone is enclosed by rocks having chlorite-and biotite-bearing assemblages. A second garnet occurrence is restricted to a sheared quartz-feldspar porphyritic rock exposed on the Bertram Property (Zone F3, Figure 057.2). This garnet occurrence also exists well within the greenschist domain. This relationship could develop because: a) the thermal regime within

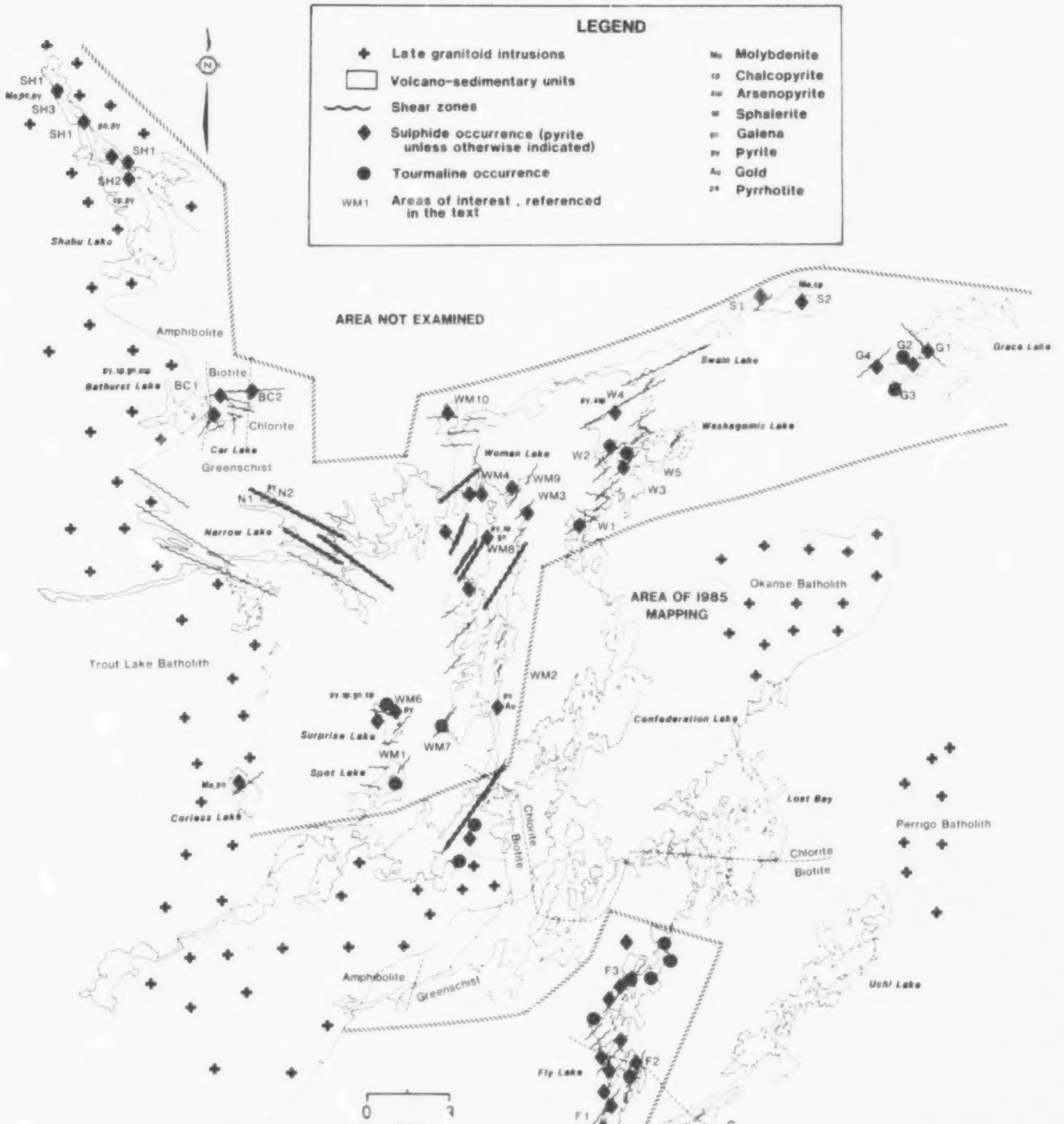

LEGEND
Late granitoid intrusions
Volcano-sedimentary units
Shear zones
Sulphide occurrence (pyrite unless otherwise indicated)
Tourmaline occurrence
WM1 Areas of interest, referenced in the text
Mo Molybdenite
cp Chalcopyrite
asp Arsenopyrite
sp Sphalerite
gn Galena
py Pyrite
Au Gold
po Pyrrhotite
N
SH1
SH3
SH2
Shabu Lake
Amphibolite
Biotite
Bathurst Lake
BC1
BC2
Chlorite
Car Lake
Greenschist
AREA NOT EXAMINED
N1
N2
Narrow Lake
Trout Lake Batholith
WM10
Woman Lake
WM4
WM9
WM3
WM8
WM2
WM6
Surprise Lake
WM1
WM7
Spot Lake
Carless Lake
S1
S2
Swain Lake
W4
Washagomis Lake
W2
W5
W3
W1
G4
G2
G1
G3
Grace Lake
AREA OF 1985 MAPPING
Okanse Batholith
Confederation Lake
Lost Bay
Perrigo Batholith
Chlorite
Biotite
Uchi Lake
Amphibolite
Greenschist
F3
F2
F1
Fly Lake
0
3
KM
Greenschist
Amphibolite

Figure 057.2. Location of D_1 and D_2 zones of simple shear, and tourmaline and sulphide mineral occurrences in the Confederation-Woman Lakes area. The width of the smaller shear zones is exaggerated. Only the Fly Lake zone of deformation was developed during D_1. The approximate location of the chlorite-biotite transition (greenschist) and the greenschist amphibolite isograd is also indicated. Some information for the area examined in 1985 (Fyon and Lane 1985) has not been included on this map.

the shear zone may have exceeded that in the adjacent rocks; b) the bulk rock composition within the shear zone differed from that of the surrounding rocks due to the influx of fluid into the shear zone; or c) the thermal regime was maintained long enough for the mineralogy within the shear zone to equilibrate by dynamic (and possibly fluid enhanced) recrystallization, while the static system outside the shear zone could not. A combination of all three factors is also possible.

Gold Potential

Within the sericitized, sheared, felsic volcanic rock, exposed along the western shore at the southern end of the lake (Zone F1), pyrite is ubiquitous and occurs as disseminations and veins along a strike length of at least 3 km. Pyrite distribution is erratic and patchy, although locally pyrite concentrations exceed 10 percent across a zone of 1 m in width. It is not certain if the sericitization and pyritization in this zone developed in response to the circulation of synvolcanic, base metal precipitating hydrothermal fluids (volcanic-associated, massive sulphide kindred), or are the expression of a late, structurally localized hydrothermal fluid influx.

On the Bertram Property (Zone F3, Figure 057.2), quartz+tourmaline veins occur within a quartz-porphyry body, a feldspar-phyric dike, and spherulitic and variolitic flows. The veins are folded and boudinaged, and locally have been sheared. The internal texture of the quartz part of the vein, where preserved, indicates that it formed by repeated crack and seal. Black tourmaline replaces both the wall rock and the crack-seal-textured vein quartz and, hence, was introduced after most of the quartz. While some of the quartz in veins shows textural evidence of having been deformed (sheared), the tourmaline grains do not. The two main showings are exposed on the western and eastern shores of the peninsula, where the main vein sets appear to trend approximately north and east, and have a steep dip. At least two vein sets exist. An earlier vein consists almost entirely of milky white quartz. These veins range up to 60 cm in width and are the most deformed. Pyrite, sphalerite, and rare galena are present in trace amounts. A later, generally narrow (<5 cm) quartz+tourmaline+ferroan carbonate vein set crosscuts the earlier, milky white quartz vein set. Pyrite is locally abundant in the wall rock of the vein system. The widest vein array (1 to 5 m) occurs in, and adjacent to, a northeast-trending shear zone, localized within a quartz-porphyry intrusion. Pyrite and magnetite occur along the western margin of the quartz-porphyry body, localized within a possible intrusion breccia zone. Magnetite also occurs persistently, as a disseminated accessory mineral, throughout the intrusion. Four of five assays of the vein system, reported by Bateman (1939, p.42), exceeded 15 g/t (~0.5 ounce gold per ton) across narrow widths (<0.3 m).

NARROW-WASHAGOMIS-WOMAN LAKES

Alteration

Chloritized Shear Zones

In most of the shear zones which cut basalt flows in these areas, chlorite is the stable alteration mineral. Calcite-filled fractures occur frequently within and adjacent to these shear zones. A small area of silicified basalt occurs at the southwestern end of Washagomis Lake (Zone W1, Figure 057.2). While this silicified zone occurs within an area where a high frequency of chloritic shear zones exists, and may therefore have developed synchronously with the shearing, the alteration appears to predate the shearing because the areas of most intense silicification do not coincide with discrete shear zones.

Carbonatized Shear Zones

Ferroan carbonate and calcite are the hydrothermal carbonate minerals observed in this area. Ferroan carbonate occurs as: a) a replacement of volcanic rock; b) discrete veins up to 2 m in width; and c) a cementing matrix within tectonic breccia zones. Generally, wall rock replacement by ferroan carbonate within shear zones is a more common characteristic of, although not restricted to, the northern part of Woman and Washagomis Lakes (Figure 057.2). Invariably, domains which have been subjected to intense replacement by ferroan carbonate also contain ferroan carbonate veins or breccia zones. Variable amounts of white mica (sericite) and sometimes pyrite also occur with the ferroan carbonate.

Most of the larger ferroan carbonate veins, exceeding 0.2 m in width, are almost exclusively restricted to D_2 shear zones. The wider veins have been boudinaged and folded and, hence, were emplaced early in the D_2 deformation event. Quartz tension fractures are ubiquitous within the deformed ferroan carbonate veins.

Tectonic breccia zones or "breccia veins", ranging in width from 0.5 to 100 cm, were observed to cut discordantly across all rock types, but appear to be more common in the felsic volcanic rocks which are found in the central Woman Lake area. These breccia zones consist of angular wall rock fragments up to 5 cm in diameter which are supported by ferroan carbonate matrix material. The fragments show little evidence of having been comminuted or flattened.

In the Woman Lake area, four zones where basalt flows have been intensively replaced by calcite were identified (Zones WM1 in the Spot Lake area, WM2, WM3, WM4 in the Woman Lake area). In these areas, intense replacement by calcite extends well beyond the discrete shear zone boundaries. Only at Zones WM1 (Spot Lake) and WM4 does the lateral extent of the calcite alteration correlate closely with the shear zone.

In the Washagomis Lake area, apple-green mica, accompanied by tourmaline and disseminated pyrite, occurs in one ferroan carbonate-altered zone (Zone W2). Sericite abundance is high in two zones (Zone W3, W4). At Zone W3, sericite abundance in sheared basaltic rock approaches 30 to 50 percent, rendering the basalt protolith into a very light coloured quartz-sericite schist. Very fine grained (<0.5 mm) pyrite is a ubiquitous trace associate in this zone. At Zone W4, spherulitic and variolitic flows have been sheared, replaced by sericite and ferroan carbonate, and cut by quartz+pyrite+arsenopyrite+ferroan carbonate veins.

Gold Potential

Chloritic Shear Zones

Quartz veins are common in the chloritized shear zones; however, these quartz veins generally are accompanied by neither significant sulphide minerals nor gold, based on past exploration activity. A preliminary assessment of their structural relationships indicates that many of these quartz veins formed early during the development of the shear zone, perhaps as tension veins. The quartz vein exposed on the Dunkin Property (Zone N1, Narrow Lake), where a large shear zone is host to a large (up to 1 m in width) boudinaged, milky white quartz vein, appears to be a larger scale manifestation of this relationship. The fluid history of these shear zones, as recorded by the vein chronology, is relatively simple, with generally one vein event recorded by the presence of a single, deformed quartz vein. A pyritic quartz vein (<10 cm) does occur to the northeast of the Dunkin zone (Zone N2); however, the gold tenor and continuity of this zone are not known. This zone appears to have received only limited surface exploration.

Shear Zones Altered to Ferroan Carbonate

Within some of the ferroan carbonate-altered shear zones, quartz and quartz+ferroan carbonate+tourmaline veins, accompanied by sulphide minerals (pyrite and rarely arsenopyrite), are present. Pyrite occurs both as a constituent in the quartz+ferroan carbonate+tourmaline veins and disseminated in the carbonatized wall rock.

In the Washagomis Lake area, four zones, possibly having gold potential, occur within ferroan carbonate-altered, northeast-trending shear zones. Only one of these zones appears to have been extensively explored (Zone W1, Figure 2). This showing consists of a quartz+ferroan carbonate vein, 60 cm in width, which is localized within a northeast-trending, chloritized shear zone. Carbonatization of the sheared, chloritic basalt wall rock does not extend more than 2 or 3 cm away from the vein. Up to 20 percent fine-grained (1 to 2 mm) pyrite occurs disseminated in the quartz+carbonate vein. Pyrite also occurs as veinlets in the chloritic wall rock, where its abundance does not exceed 5 percent. This zone appears to have been diamond drilled.

Zone W2 consists of ferroan carbonate+tourmaline (?) veins accompanied by disseminated pyrite. Locally, an apple-green mica is present in the carbonatized basalt wall rock. This zone is of interest, not only because of the disseminated pyrite, but also because of the presence of the apple-green mica.

In Zone W3, very fine grained (<0.25 mm), sparsely ferroan-carbonatized basalt. No quartz veins were observed in this shear zone.

Quartz+ferroan carbonate veins up to 0.5 m in width occur within a unit of sheared, spherulitic flow exposed along the northern shore of Washagomis Lake (Zone W4). Pyrite, locally in amounts exceeding 10 percent, and lesser amounts of arsenopyrite, occur in the quartz veins and in the sericitized wall rock. The zone, where replacement by sericite and ferroan carbonate is most intense and quartz+carbonate veins are most abundant, has a strike length of approximately 50 m along the lakeshore; however, the zone does not appear to extend more than 20 m to the north. A very fine grained dusting of a silvery iron oxide (hematite?) occurs in the less altered and sheared spherulitic rocks to the north of the lakeshore showing. Quartz+ferroan carbonate+tourmaline veins, ranging from 1 to 5 cm in width, occur within a ferroan carbonate alteration zone located in the central part of Washagomis lake (Zone W5). Pyrite is a common constituent of the veins, but also occurs in the altered wall rock. This zone may be part of Zone W3.

Exposed at Zone WM5, on Surprise Lake, is a quartz+sulphide vein which ranges in width from 0.5 to 1 m. Pyrite, galena, rare chalcopyrite, and rare sphalerite occur immediately adjacent to the vein in the chloritized wall rock. Pyrite occurs sparsely in the quartz vein. The vein trends 050° and dips steeply to the south. Across the lake from this showing is a west-northwest-trending shear zone, in which a possible dioritic rock has been replaced by ferroan carbonate (Zone WM6). Quartz+tourmaline veins are common in the altered rock, although pyrite is not abundant. A number of feldspar-porphyry dikes occur in this zone. This zone has been diamond drilled.

At the southwestern end of Shanty Bay (Woman Lake; Zone WM7), a quartz-veined zone is developed in a north-to northeast-trending shear zone which is localized along the contact between spherulitic flows and a possible dioritic rock. The mafic rock has been replaced by ferroan carbonate. Several generations of carbonate, quartz, and quartz+tourmaline veins are present. Early in the vein chronology are ferroan carbonate veinlets (<2 cm) and quartz veins (up to 5 cm in width). A quartz+tourmaline vein, up to 0.5 m in width, postdates the earlier quartz and carbonate veinlets and cuts the deformed mafic rock. Later quartz+ferroan carbonate veins crosscut the quartz+tourmaline and carbonate vein sets. At the southwestern end of this showing, a large, milky white quartz vein attains a width of at least 10 m. At the margin of this wide vein are a number of narrower (10 cm) quartz veins which enclose wall rock fragments, giving the impression of a quartz-vein-cemented, wall rock breccia. The chronological position of this vein is not known. Sulphide minerals are not abundant at the showing; however, the complex vein and structural histories of this zone indicate that several episodes of fluid migration took place through this zone.

A number of wide (>1 m) ferroan carbonate veins, cut by later quartz veins, occur within the shear zones on Woman Lake. One such vein system (Zone WM8) also carries sparsely disseminated, fine-grained pyrite (<0.5 mm), sphalerite, and galena. Several northeast-trending shear zones on Woman Lake also carry disseminated pyrite, with variable amounts of pyrrhotite (WM9, WM10), without accompanying quartz or ferroan carbonate veins. Sulphide mineral abundance is low (5 percent).

SWAIN LAKE

Alteration

Wall rock replacement by chlorite and the presence of calcite-filled extension fractures are the typical features of the shear zones developed in mafic rock exposed on Swain Lake. A sheared outcrop of polymictic conglomerate, exposed at the northeastern end of the lake (Zone S1, Figure 057.2), has been altered to sericite, accompanied by disseminated and veined pyrite. Parts of a feldspar-quartz porphyritic intrusion, which crops out at the eastern end of the lake, also have been intensely sericitized (Zone S2, Figure 057.2).

Gold Potential

Two areas of interest were observed on Swain Lake. Up to 10 percent pyrite occurs as disseminated grains and veinlets in the sericitized shear zone developed in polymictic conglomerate (Zone S1, Figure 057.2). Along strike to the northeast, less pyritic material crops out, although the exposed outcrop appears to lie on the margin of the most intensely sheared and altered zone.

Exposed at the eastern-most end of the lake is a sericitized feldspar-quartz porphyry intrusion (Zone S2, Figure 057.2). Where examined, this body is cut by quartz+molybdenite+chalcopyrite veinlets (<1 cm), which are in turn cut by ferroan carbonate veins. Fine-grained (<0.25 mm) pyrite is ubiquitously, but sparsely, disseminated in the sericitized intrusion. Due to time limitations, not all available outcrops of this intrusion were examined; however, the type of alteration (phyllic) and the presence of molybdenite+chalcopyrite-bearing quartz veins are characteristics which resemble those of felsic intrusions known or inferred to define magmatic centres to gold camps (Macdonald 1984, Mason and Melnik 1986).

BATHURST-CAR LAKES

Alteration

Sheared mafic volcanic and intrusive rocks are replaced by chlorite. Calcite-filled extension veins are common within the shear zones. Ferroan carbonate veins rarely occur.

Gold Potential

Two areas of interest were examined, the Bathurst Mine Property (Zone BC1, Figure 057.2) and the Price-Logan showing (Zone BC2, Figure 057.2), both of which are described by Bruce (1928). Although most of the trenches on the Price-Logan Property (Zone BC2) are partially filled, the zone of interest lies within an east-trending shear zone which attains a width of 5 m. Quartz veins and silicified zones are not common, but, where observed, both are deformed. Sulphide mineral abundance outside the silicified pods is low. Sericitic quartz porphyry dike material was found in the trench dumps, but none was observed in place.

Several zones have been developed at the Bathurst Mine, the most prominent of which includes the #1, #2, #3 and #4 veins. These systems consist of east-to east-southeast-trending shear zones in which quartz veins, up to 0.5 m in width, are localized. These shear zones attain widths in excess of 3 m. Pyrite, accompanied by ferroan carbonate and chloritic wall rock fragments, is present in some of the quartz veins; however, pyrite does not appear to be a major constituent of the vein systems. The northerly trending #12 vein zone is an exception in this regard, where traces of arsenopyrite, pyrite, chalcopyrite, and galena occur with narrow (<3 cm) quartz veins in a sheared pillow basalt. Most of the quartz veins observed are milky white in colour and are coarse grained (0.5 to 2 cm); however, the quartz vein in the #3 zone is very fine grained and blue in colour. The reduced grain size of the blue quartz vein may have been the result of mylonitization.

Many of the quartz veins on this property are flat lying (Bruce 1928, p.40-41). Although the kinematic analysis of shear zones is preliminary, the orientation of these "flat" quartz veins is consistent with their formation as early tension veins formed in response to a horizontal, maximum stress.

Felsic dikes are common on the Bathurst Property. These dikes have experienced some of the shearing, but their geometrical relationship with respect to the mineralized quartz veins was not observed.

Virtually all of the minor shear zones observed on Car Lake, ranging from 5 to 100 cm in width, contain narrow, deformed quartz veins. These veins appear to have developed as tension veins early in the development of the shear zone, and hence, underwent a significant increment of strain. These minor shear zone/quartz vein systems appear to model accurately the larger systems observed on the Bathurst Property.

GRACE LAKE

Alteration

Intermediate pyroclastic deposits and clastic sedimentary rocks, affected by a northwest-trending shear zone (Zone G1, Figure 057.2), are chloritized and sericitized. Pyrite occurs locally within this shear zone. Replacement of a possible dioritic rock by ferroan carbonate has taken place within a northeast-trending shear zone (Zone G4, Figure 057.2). Disseminated pyrite and narrow (<2 cm) quartz veins are present within the sheared and altered rock.

Gold Potential

Four showings having gold potential were recognized. A wide northwest-trending shear zone is localized at or near the contact between clastic metasediments and intermediate pyroclastic deposits, and contains a disseminated pyrite zone about 1 m in width (Zone G1, Figure 057.2). The pyrite occurs as veinlets and disseminated porphyroblastic grains, 2 to 3 mm in diameter, but is not present in amounts exceeding 10 percent.

The Sol D'Or Mine Property (G2. Figure 057.2) has been described by Johns (1976). New observations relevant to this property are:

1. The dominant lithology appears to be intermediate pyroclastic tuff-breccia. but those rocks exposed near the shaft area have been intensely silicified. rendering rock type identification less certain.
2. An apple-green mica is erratically distributed in the most intensely silicified domains.
3. An early milky quartz vein set has been brecciated, and tourmaline cements the vein quartz fragments; however, it is not known if higher gold values accompany this tourmaline.
4. Quartz and tourmaline occur together in east-trending, moderately south-dipping vein sets, up to 40 cm in width and as a matrix in which brecciated and silicified wall rock fragments "float", indicating that the silicification event predated or was synchronous with the tourmaline event.
5. Tourmaline occurs disseminated in the wall rock as fine (1 mm), star-shaped crystal arrays.
6. Narrow (<2 cm) quartz veins crosscut the tourmaline+quartz veins, indicating that a late quartz veining event took place.

In an area south of the southwestern arm of Grace Lake (G3, Figure 057.2), intermediate and felsic flows crop out. Tourmaline+quartz veinlets (<2 cm wide) occur ubiquitously in this area. Given the association of tourmaline with gold mineralization in the Uchi Belt, the frequent tourmaline occurrences in this area may have economic significance.

Northeast of the southwestern arm (Zone G4), a northeast-trending shear zone is localized in a gabbroic rock. Wall rock within this zone is replaced by ferroan carbonate and disseminated pyrite, and narrow (<2 cm) quartz+tourmaline veins are present in the altered shear zone. This zone has been diamond drilled.

SHABU LAKE AREA

Alteration

A quartz-feldspar porphyritic unit crops out along the central and northwestern parts of the lake. This unit has been sericitized and replaced by ferroan carbonate in the northwest (Zone SH1, Figure 057.2). Sericite-poor outcrops of this rock were observed at the southern end of the lake.

Gold Potential

A zone of sparsely disseminated pyrite occurs within a quartz-feldspar porphyry unit along a strike length of nearly 3 km (Zone SH1, Figure 057.2). This porphyry is sheared and altered to ferroan carbonate and sericite. Pyrite occurs as disseminated grains and veinlets, but does not exceed 5 percent by mode. The porphyry unit is of uncertain origin; both intrusive and extrusive characteristics were observed in various outcrops. The sericite alteration is not persistent along strike; the most intensely sericitized areas of the porphyry occur along the northwestern arm of the lake. Areas of more abundant disseminated pyrite correspond with domains of more intense sericitization. Minor amounts of chalcopyrite occur as veinlets within biotite-bearing wackes within, or subparallel to, the porphyry zone (Zone SH2, Figure 057.2). Minor, boudinaged quartz veins also occur in this copper zone. Disseminated pyrrhotite and rare chalcopyrite occur in a garnet-and diopside-bearing calc-silicate rock exposed at the northern end of the lake (Zone SH3, Figure 061.2). Pyrite and traces of molybdenite also occur in this material, generally where quartz veins are present.

FAVOURABLE CHARACTERISTICS POINTING TO GOLD MINERALIZATION

Several features are common to those zones which have had a record of gold production and serve as a guide to understand and evaluate the gold potential of new areas:

1. Auriferous zones are localized by structural features, expressed as shear zones and/or as planar loci of repeated fluid migration, such as crack-seal quartz veins.
2. Those structures which are auriferous were active during the D_2 or D_3 deformation events; the gold potential of all D_1 structures is less well understood, although one in particular (Fly Lake Zone of Deformation) has interesting alteration and sulphide mineralization.
3. Where the host rock has a mafic bulk composition, the typical alteration is replacement by ferroan carbonate and/or white or green mica; felsic rocks are generally sericitized with lesser ferroan carbonate replacement.
4. Late felsic dikes are present in the immediate area, if not within the zone of interest.
5. Chronology indicates that the auriferous zones had a very complicated and lengthy history involving repeated both fluid influx and deformation.
6. Tourmaline is a frequent mineralogical associate.

A common vein paragenesis is observed at many properties where tourmaline accompanies quartz in veins. The Sol D'Or Mine, the Shanty Bay showing (Zone WM7, Figure 057.2), the Bertram showing and the Jackson-Manion Property are all characterized by the following vein chronology:

1. The early veins consist of quartz and/or ferroan carbonate.
2. The early quartz veins were brecciated and cemented by tourmaline or were crosscut by tourmaline+quartz veins.
3. A later generation of quartz (with, or without, ferroan carbonate) veins postdated the tourmaline-bearing veins.

At the Jackson-Manion Mine, gold precipitation accompanied the tourmaline event, but it is not certain if such was the case at the other properties.

In the context of the favourable characteristics listed above, and the vein chronology recognized in some of the past gold producing areas, four of the areas previously outlined, located north of Fly Lake, have special merit. At the eastern end of Swain Lake, an altered feldspar-quartz porphyry intrusion crops out. Quartz veins cut the altered intrusion and carry molybdenite and trace chalcopyrite. Given that molybdenum-copper-gold metal zonation, developed symmetrically with respect to late felsic intrusions, is recognized in the Geraldton (Macdonald 1984) and Timmins areas (Mason and Melnik 1986) pyritic and altered shear zones in this area, including those near Grace Lake, should receive careful consideration. Late felsic intrusions also occur in proximity to the Jackson-Manion (Fyon and Lane 1986), Bathurst and Car Lakes, and Surprise Lake areas, all of which have favourable alteration, and complex quartz and tourmaline vein and structural histories.

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058. Regional Setting of the Goldlund Mine, and Other Gold Occurrences in the Crossecho Lake Area, Northwestern Ontario

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

The Crossecho Lake area (Figure 058.1) overlaps portions of Webb, Laval, Echo, McAree, and Pickerel Townships, halfway between the communities of Sioux Lookout and Dinorwic, at approximately 92°25'W Longitude and 49°55'N Latitude. Highway 72 passes through the southeastern perimeter of the study area and logging and cottage roads provide further access. The Goldlund Mine, the most developed gold occurrence in this segment of the belt, and the adjoining Camreco Property, which includes an exploration shaft, are situated between Crossecho Lake and Highway 72.

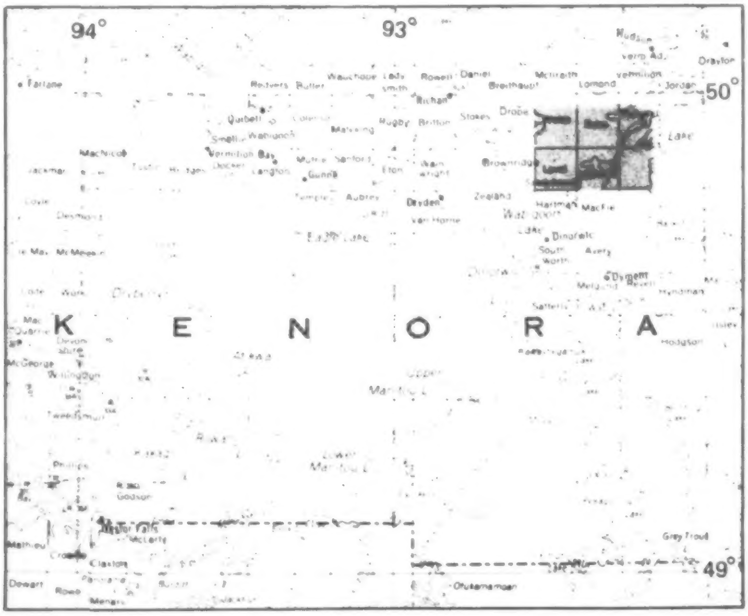
PREVIOUS STUDIES

Parts of the study area were previously mapped on a regional scale by Satterly (1943), Armstrong (1951), Johnston (1969), Palonen (1976), Palonen and Speed (1974, 1975, 1977), Page and Christie (1930), and Page (1984). Compilations by Breaks *et al.* (1976) and Blackburn (1981) include the area. Webb (1948) and Chisholm (1951) provide detailed accounts of the geology of the Goldlund (Lunward, Newlund) Mine. Unpublished company reports, providing information about the geology and geophysics of the Goldlund Mine and vicinity, are in the Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Sioux Lookout. Much of this information is summarized in Page (1984). Tarbush Lode Mining Limited and Camreco Incorporated are presently the most active exploration companies within the study area.

Berger (this volume) mapped McAree, MacFie, and Avery Townships, overlapping the Crossecho Lake study area, on a 1:20 000 scale (Figure 058.1), and determined that the gold occurrences in these townships occur in three environments:

"1. in large quartz veins in sheared and altered mafic metavolcanics [and feldspar porphyry]
2. in silicified and carbonate altered zones at the apparent intersection of northeast- and east-northeast-trending lineaments
3. in sulphide stringers within iron-rich metasediment"

The altered structural zones hosting the types (1) and (2) gold occurrences are related to two major northeasterly and easterly trending fault and shear systems which converge near Dinorwic (Figure 058.1). The northeast-striking system includes the Vermilion Lake Fault and numerous shear zones passing through Dinorwic, Sandybeach, and Minnitaki


94°
93°
50°
49°
K E N O R A
Vermilion Bay
Dryden
Dinorwic
MacFie
Avery
Drayton
Jordan
Rowell
Daniel
Brownridge
Zealand
Hartman
Mafie
Wainwright
Aubrey
Eton
Gunne
Langton
Docker
Redvers
Butler
Richan
Britton
Stokes
Drope
Fairlane
MacNicol
Jackman
Desmond
Webb
McIlraith
Vermilion
Lomond
Melgund
Hyndman
Satterly
Grey Trout
Godson
Phillips
Claxton
Mather
Dewart
Menary

LOCATION MAP Scale : 1:1 584 000 or 1 inch to 25 miles.

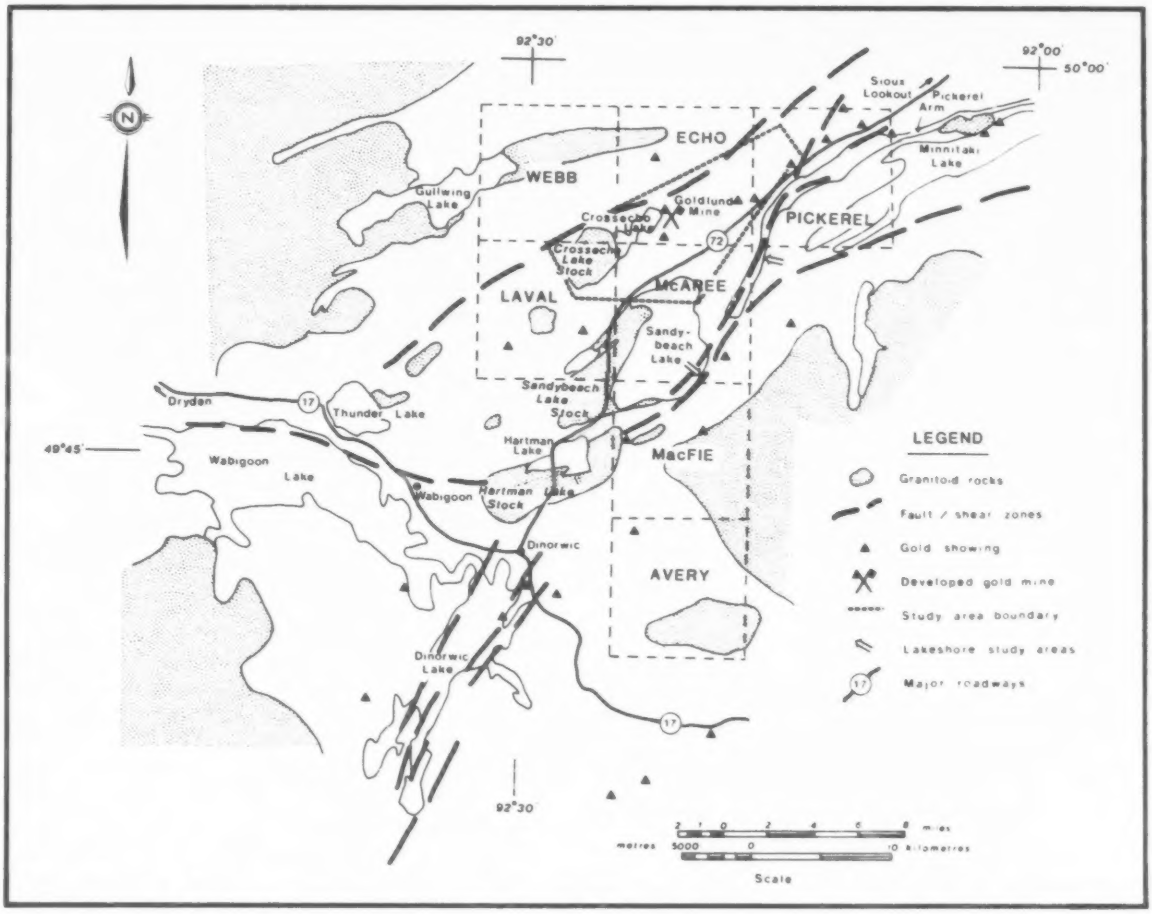

92°30'
92°00'
50°00'
N
Sioux Lookout
Pickerel Arm
ECHO
Minnitaki Lake
WEBB
Gullwing Lake
Goldlund Mine
Crossecho Lake
PICKEREL
Crossecho Lake Stock
72
McAREE
LAVAL
Sandybeach Lake
Sandybeach Lake Stock
Dryden
17
Thunder Lake
Hartman Lake
49°45'
Wabigoon Lake
Wabigoon
Hartman Lake Stock
MacFIE
LEGEND
Granitoid rocks
Fault / shear zones
Gold showing
Developed gold mine
Study area boundary
Lakeshore study areas
Major roadways
Dinorwic
AVERY
Dinorwic Lake
17
92°30'
2 1 0 2 4 6 8 miles
metres 5000 0 10 kilometres
Scale

Figure 058.1. *Location of the study area, showing major structural lineaments, granitoid stocks, and gold occurrences.*

Lakes (Blackburn 1981). The easterly trending Wabigoon Fault and associated shear system abut or converge into this system from the west in the vicinity of the granitoid Hartman Lake Stock (Figure 058.1). Several other granitoid stocks, including the Sandybeach Lake and the Crossecho Stocks (Figure 058.1), are affected predominantly by the northeasterly shear/fault system. The Goldlund Mine is located near the faulted northeastern end of the Crossecho Stock, and its structural and/or thermal setting may have been influenced by the stock.

This report summarizes work undertaken during the initial field season of a two-year joint project with B.R. Berger (Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto). The initial field work involved detailed lakeshore and roadside geology, in addition to pace and compass traversing of the field area outlined on Figure 058.1. The purpose of this work was to investigate the timing and geological significance of the northeasterly striking, steeply dipping, shear and fault zones, as a prelude to a later study of the more complex confluence of the northeasterly and easterly structural systems. Emphasis was thus placed on reassessing the structural and metamorphic/hydrothermal features on a regional scale, rather than on remapping areas already well mapped by Satterly (1943), Armstrong (1951), and Johnston (1969), or on mapping the Goldlund Mine area or other gold occurrences in more detail than already accomplished by Webb (1951), Page (1984), and company geologists.

Although the major structures mentioned above were assumed to have exerted first order controls on the auriferous mineralization, the granitoid stocks involved in these stuctural systems may have exerted important second order structural and/or thermal controls. Therefore, the structural state and timing of emplacement of these plutons will be addressed specifically during the course of the project.

GENERAL GEOLOGY

LITHOLOGIES

The Crossecho Lake area (Figure 058.2) is underlain predominantly by mafic, intermediate, and felsic metavolcanic rocks which pass gradationally into metasedimentary rocks. The metavolcanic rocks were intruded by early metadiabases, which locally display

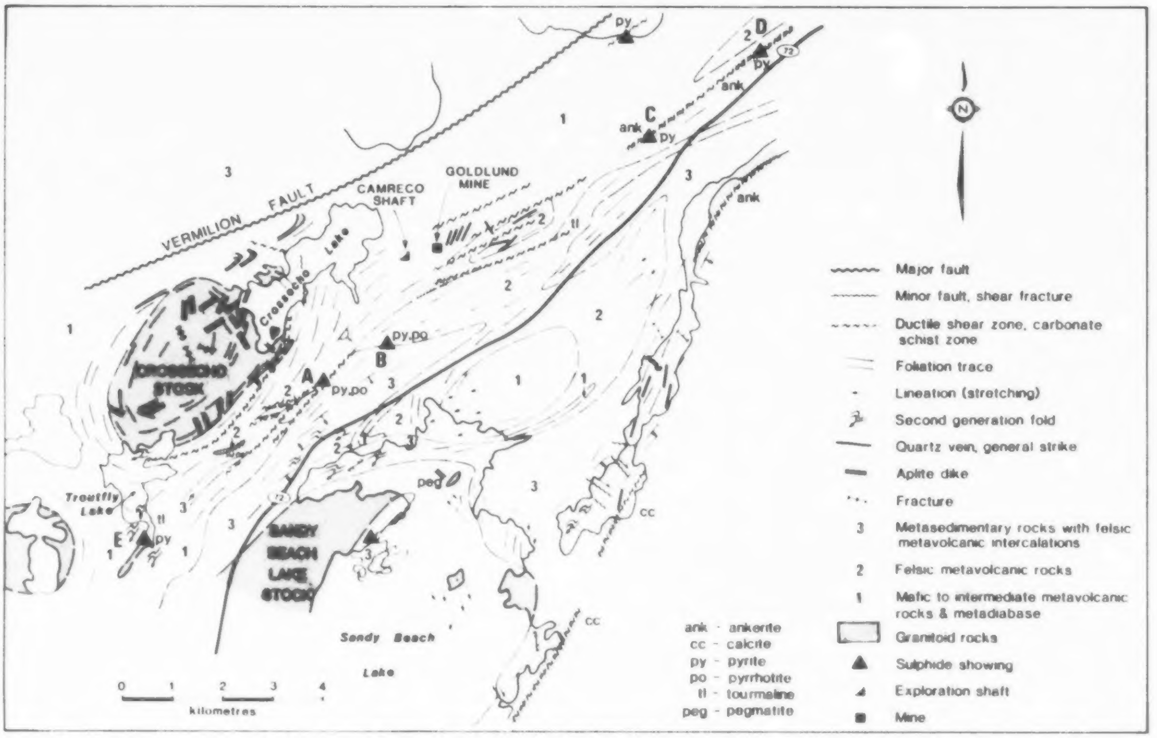

VERMILION FAULT
CAMRECO SHAFT
GOLDLUND MINE
CROSSECHO STOCK
Crossecho Lake
SANDY BEACH LAKE STOCK
Sandy Beach Lake
Troutfly Lake
A
B
C
D
E
py
py,po
ank
tt
peg
cc
72
1
2
3
N
0 1 2 3 4
kilometres
ank - ankerite
cc - calcite
py - pyrite
po - pyrrhotite
tl - tourmaline
peg - pegmatite
Major fault
Minor fault, shear fracture
Ductile shear zone, carbonate schist zone
Foliation trace
Lineation (stretching)
Second generation fold
Quartz vein, general strike
Aplite dike
Fracture
3 Metasedimentary rocks with felsic metavolcanic intercalations
2 Felsic metavolcanic rocks
1 Mafic to intermediate metavolcanic rocks & metadiabase
Granitoid rocks
Sulphide showing
Exploration shaft
Mine

Figure 058.2. *Geology of the study area, emphasizing the main structural features, and showing the location of the Goldlund Mine, Camreco Shaft, and other sulphide mineral occurrences with gold potential.*

rhythmic layering and composite intrusive relationships. Gradation into massive flows, and local complex interfingering relationships with massive and pillowed flow rocks, suggest that these metadiabases are synvolcanic. Widespread feldspar and feldspar-quartz porphyry dikes intruded both metavolcanic and metasedimentary rocks before the emplacement of the Sandybeach Lake Stock. Contact relationships between the porphyry dikes and the Crossecho Stock were not observed, however, a remarkable resemblance between the commonly quartz-phyric granitoid rocks of the stock and the feldspar-quartz porphyry dikes in the Goldlund Mine area may either mask sharp contacts, such as those observed between the metavolcanic rocks and the stock, or indicate a continuum between the stock and some of the dikes.

The Crossecho Stock is an ovoid body of leucotonalite (less than or equal to 5 percent ferromagnesian minerals), characterized by numerous planar aplite and subordinate, quartz-filled extension fractures. The aplites and veins are markedly more abundant where the main granitoid phase is well foliated, suggesting that their emplacement was related to deformation while the magmatic-pneumatolytic system was still active, probably during the upwelling of the stock and during the development of the predominant regional structures.

The Sandybeach Lake Stock is a larger, more mafic body of hornblende-bearing quartz monzonite, with pegmatite and local aplite seams within, and next to, its northwestern margin. Narrow dikelets, strongly resembling the main phase of the Sandybeach Lake Stock, occur up to 5 km north of its main exposure, along Pickerel Arm and the southern end of Crossecho Lake.

METAMORPHISM

The regional metamorphic grade varies from middle greenschist facies at the northeastern end of the Crossecho Lake study area, to lower amphibolite facies and locally higher in the southeast. In general, the grade rises toward the Sandybeach Lake Stock. Metasedimentary rocks throughout most of the area are biotite-muscovite-quartz-plagioclase schists, which are commonly characterized by andalusite porphyroblasts in the southeast. Mafic rocks range from greenschists to amphibolites. Cordierite- and sillimanite-bearing metasedimentary rocks occur in several belts of secondary folding along the northern side of the Sandybeach Lake Stock. The Sandybeach Lake Stock is therefore thought to have had an important thermal influence on the regional metamorphic grade.

STRUCTURAL IMPRINT AND TIMING

The predominant structural imprint in the area, affecting the metasedimentary, metavolcanic, and metadiabasic rocks, is an inhomogeneous, generally steep, northeast-striking foliation. The foliation intensifies along lithological contacts and within relatively micaceous pelitic beds, producing narrow, high strain zones of minor structural significance. The main foliation is generally oriented nearly parallel to, but slightly counterclockwise from, bedding. Bedding faces southeast, but local reversals in bedding-cleavage relationships, and rarer northwesterly topping directions, suggest that either the foliation is axial planar to steeply plunging folds, or entirely postdated earlier folding, warping, or differential tilting.

The predominant foliation intensifies markedly into steep, northeast-striking, ductile shear zones several metres wide, which occur within the traversed study area and through Pickerel Arm and the southeastern side of Sandybeach Lake (Figure 058.2). These zones are characterized by phyllonitic fabrics, intense carbonate alteration (sericite-ankerite-chlorite in the northeast and biotite-calcite in the rest of the upper greenschist and higher grade terrain), and the presence of both extremely deformed, buckled, transposed and fragmented, and less deformed, quartz veins. Most ductile shear zones are also characterized by the presence of one or more sets of crenulations, and, more rarely, local intrafolial folds of the strong schistosity. Displacement senses on the main shear zones, determined from foliations, lineations, and vein geometry, suggest that most of them involved both pure shear and combined horizontal and vertical simple shear components that varied widely in proportion and sense of vertical displacement gradient from one area to another. The deformation associated with the development of these ductile shear zones both pre- and postdated the intrusion of the main phases of both the Sandybeach Lake and Crossecho Stocks. Aplites related to the Crossecho Stock clearly crosscut the mylonitic fabrics, but are locally openly buckled across them, and inclusions in the margins of both stocks display foliations which predated their incorporation into the contact zone. However, strong foliations related to the shear zones are observed locally in both stocks, particularly near their margins.

The main foliation and compositional layering show moderate to gentle dips north of the Sandybeach Lake Stock, and a fully closed structural dome mapped by Berger (this volume) and shown on Figure 058.2, suggests either the interference of two large scale folds, the second post-dating the formation of the predominant fabric, or diapirism coinciding with the development of the predominant regional fabrics. In this location, a granitoid dome probably underlies the interference pattern.

Another secondary, outcrop-scale, phase of folding is also indicated by predominantly Z-folds of bedding and the main foliation within two northeasterly trending belts along the northerly lobes of the Sandybeach Lake Stock (Figure 058.2). These zones show a crenulation (second foliation) in micaceous, pelitic metasediment beds and also in the crystallization of post-early foliation, precrenulation staurolite, staurolite-rimmed garnet, and syncrenulation cordierite, as well as numerous deformed quartz lenses locally surrounded by anomalous concentrations of either staurolite or cordierite, suggestive of vein-related metasomatism. Planar quartz veinlets and porphyroblast-enriched seams also fill fractures axial planar to the Z-folds in a few outcrops. Near-peak metamorphic temperatures thus persisted during this secondary deformation event, and the localization of deformation was possibly related to the Sandybeach Lake Stock. Similar Z-folds in foliation are found along the southern side of the Crossecho Stock. This pattern suggests that the upwelling of the granitoid stocks overlaps both the last stages of the regional deformation, producing the local, second phase folds, and the development of the major ductile shear zones (above).

The latest phase of deformation involves relatively minor chevron and kink folds in bedding, foliation, and the crenulation (where present) about northwesterly and northerly axial planes associated with minor similarly oriented, dextral faults and shear fractures. Northwesterly to westerly striking, barren extension fractures are also common.

Undeformed to highly deformed quartz veins, from millimetres to tens of centimetres wide, are common throughout the area. Most of the veins are barren or contain very minor sulphide mineralization, and lack marginal alteration. Deformation of the veins ranges from mild buckling, through asymmetric folding and boudinage, to the total disaggregation common in the older veins in the ductile shear zones described above. Where the orientation of the veins or envelopes of folded veins can be estimated or measured, original orientations were predominantly either: a) at low to moderate angles counterclockwise to the main foliation, or b) at high angles to main foliation, either nearly perpendicular to it or sited along the minor, regional, northwest- to locally north-striking fractures. In many of the relatively competent rock masses, such as a deformed rhyodacite dome near the Goldlund Mine, quartz veinlets occur in sets conjugate to the main foliation, although the veinlets that formed counterclockwise to the foliation are slightly larger and more numerous. Nevertheless, veins clockwise to the main foliation were noted locally, even in the relatively incompetent metasedimentary schists and ductile shear zones.

SETTING OF GOLD MINERALIZATION

Gold mineralization in the area is associated with quartz veining and carbonatization in two contrasting settings:

1. in sets of brittle extension fractures in structurally competent intrusive rocks (transverse vein mineralization style)
2. associated with the steep, northeasterly striking ductile shear zones (shear zone-hosted mineralization style)

The Goldlund Mine, and nearby occurrences, display the first style of mineralization, and several prospects to the northeast and southeast of the mine area represent the second.

TRANSVERSE VEIN STYLE MINERALIZATION: GOLDLUND MINE SETTING

The terrain surrounding the Goldlund Mine is underlain by a mainly mafic to intermediate metavolcanic complex which includes massive and pillowed

Photo 058.1. *West-northwest-dipping, quartz-filled extension fractures in altered metadiabase on the southern wall of the open cut, No. 1 Zone, Goldlund Mine.*

metabasalt, variolitic metabasalt, locally porphyritic andesite and dacite, and abundant intercalated pyroclastic rocks. The most widely distributed pyroclastic rock type is a breccia composed of hornblende and/or feldspar-phyric fragments, and a matrix containing hornblende and, less commonly, plagioclase crystals. These rocks are cut by quartz-phyric felsite dikes, related to a rhyodacite domal complex to the southeast, and by several metadiabase sills and/or dikes. Some of the latter are clearly composite and locally display rhythmic layering; some phases of the composite bodies are plagioclase-rich and display both gradational and sharp contacts with more mafic metadiabase.

The metavolcanic and subvolcanic rocks are cut by feldspar and feldspar-quartz porphyry dikes. Some of the porphyry dikes of this area are regionally anomalous in that they contain profuse, coarse, quartz phenocrysts and highly foliated inclusions of mafic to intermediate metavolcanic rocks and feldspar-phyric dacite derived from the host metavolcanic complex.

North-northeasterly and northeasterly striking, highly carbonatized ductile shear zones occur to the northwest of the Goldlund Mine area and extend down the southeastern side of Crossecho Lake, where they are complicated by the interference of several more northerly striking brittle fault zones in the area of the lake and, possibly, by more easterly striking interference structures to the south-southeast. They are also exposed locally several kilometres southeast of the mine area, where they are developed preferentially along contacts such as that between the metasedimentary and felsic metavolcanic units. They are not prominent in the immediate vicinity of the mine and in the other nearby mineralized occurrences, which show only the effects of the main, inhomogeneous, regional foliation in the less competent metavolcanic rocks and contact zones, and the more brittle effects of the transverse extension fractures in the more competent intrusive rocks.

The gold mineralization of the Goldlund Mine and related occurrences, described thoroughly by Webb (1948), Armstrong (1951), Chisholm (1951) and Page (1984), is sited in the brittely deformed, competent intrusions. In brief, the mineralization is related to multiple, clustered sets of northerly to north-northeasterly striking, westerly dipping quartz + iron carbonate veins which fill the transverse fractures (Webb 1948, Chisholm 1951) in the composite metadiabase intrusion (Photo 058.1) and crosscutting feldspar-quartz porphyry dikes (Figure 058.3). The veins are surrounded by narrow to broad, cream to pink coloured, haloes of silicified, albitized, and carbonatized wallrock (for example, *see* Chisholm 1951, Page 1984). The metadiabase and anorthositic metadiabase are variably bleached by carbonatization and quartz impregnation in areas traversed by the veins, even outside the boundaries of the prominent alteration haloes. This may be the reason why the intrusions were referred to as granodiorite bodies by earlier workers. Metallic minerals within the veins, and alteration haloes, are predominantly pyrite and ilmenite, with subordinate galena, grey telluride, chalcopyrite, and rare visible gold.

Surface exposures of zones of abundant transverse veining and related alteration are concentrated within a 3.5 by 1 km belt centred around the Goldlund Mine. The metadiabase bodies, which form the main host to the mineralization, extend much further, at least 4 km to the southwest and at least 9 km to the northeast, where they are locally involved in the second style of mineralization.

SHEAR ZONE HOSTED MINERALIZATION

Other potentially auriferous showings are sited along, or next to, highly carbonatized and quartz-veined fissile zones (Figure 058.2). The southeastern showings (A, B) are located next to the sheared contact between the predominantly semipelitic and pelitic metasedimentary unit and a felsic metavolcanic unit in a pyritic and pyrrhotitic band. This band may have originated as one of the sulphide-rich ironstone bands commonly associated with the two units (Berger, this volume). The northwestern showings (C, D) are sited in quartz-veined, heavily ankeritized, metavolcanic and metadiabasic rocks; feldspar porphyry is also present in showing C (Lun-Echo). Showing E comprises quartz fracture fillings in a small, carbonatized body of fine-grained granite.

CONCLUSIONS

Field work to date suggests that the Crossecho and Sandybeach Lake Stocks were emplaced during regional deformation that was responsible for the predominant structural grain and numerous, commonly carbonate-rich, ductile shear zones that formed during peak or near peak metamorphic conditions. The granitoid stocks may have influenced both the structural geometry and the hydrothermal-carbonothermal circulation along these zones.

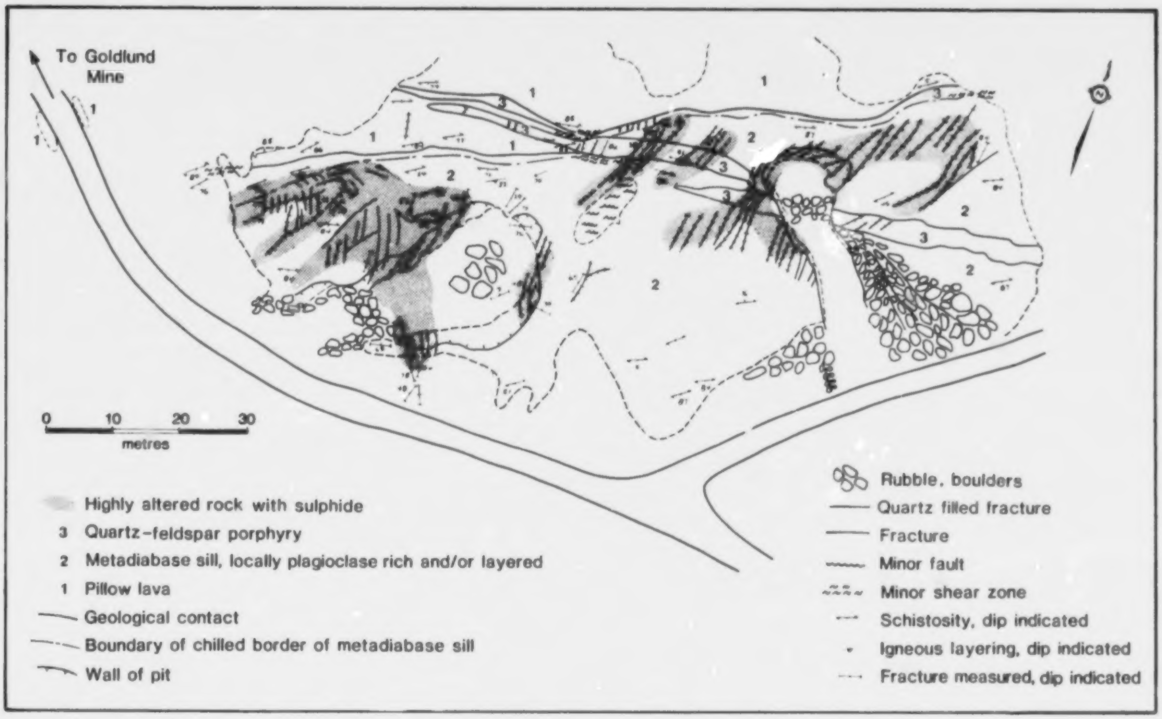

To Goldlund Mine
1
2
3
0 10 20 30
metres
Highly altered rock with sulphide
3 Quartz-feldspar porphyry
2 Metadiabase sill, locally plagioclase rich and/or layered
1 Pillow lava
Geological contact
Boundary of chilled border of metadiabase sill
Wall of pit
Rubble, boulders
Quartz filled fracture
Fracture
Minor fault
Minor shear zone
Schistosity, dip indicated
Igneous layering, dip indicated
Fracture measured, dip indicated

Figure 058.3. *Nature of quartz-filled fractures related to mineralization and alteration in a metadiabase sill at the eastern extremity of the No. 1 Zone, Goldlund Mine.*

Quartz veins filled extension fractures throughout the area during all stages of the deformation, and exhibit all degrees of deformation. Most are barren of metallic minerals and lack marginal alteration. However, pervasive quartz veining or silicification, accompanied by pyritization, which occurs locally within calcite-impregnated, biotite bearing ductile shear zones (south) and ankeritic ductile shear zones (northeast), are potentially auriferous: they are found affecting mafic and felsic metavolcanic, metadiabasic, and metasedimentary rocks.

The mineralized zones of the Goldlund Mine area occur in segments of synvolcanic metadiabase sills or dikes, and in crosscutting quartz-feldspar porphyry dikes, which are traversed by concentrations of closely spaced, subparallel, planar, extension fractures. These fractures are filled with quartz and carbonate, and moderate to intense silicification, carbonatization, and albitization of the wallrock has occurred. The type of alteration is similar to that encountered in the veined and mineralized showings located within shear zones, and the geometry of the extension veinlets is not regionally anomalous; however, the high concentration and lack of substantial postemplacement deformation of the veins, and the overall style and volume of associated alteration are regionally unique. The factors responsible for this unique structural and hydrothermal setting will be the subject of continued investigation.

ACKNOWLEDGMENTS

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059. Mineralization of the Mishibishu Lake Greenstone Belt

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INTRODUCTION

During the 1986 field season the Mineral Deposits and Precambrian Geology Sections of the Ontario Geological Survey completed the second year of a three-year helicopter-supported project to map the geology of the Mishibishu Lake greenstone belt, and of the mineral showings within it. Regional mapping of the belt (Bowen and Logothetis 1985) continued at a scale of 1:15 840 (1 inch to 1/4 mile) (*see* Bowen, this volume), and several selected mineral showings were mapped at more detailed scales.

The area encompassed by the project is 35 km west of Wawa and recently became accessible by gravel road from Highway 17 (approximately 30 km north of Wawa) into Muscocho Explorations Limited's Magnacon underground development on Macassa Creek (Figure 059.1). The majority of the belt is still only accessible by float plane or helicopter. The project area is bounded by Latitudes 48°10'00"N and 47°54'30"N, and Longitudes 85°00'00"W and 86°00'00"W, an area of some 2046 km^2.

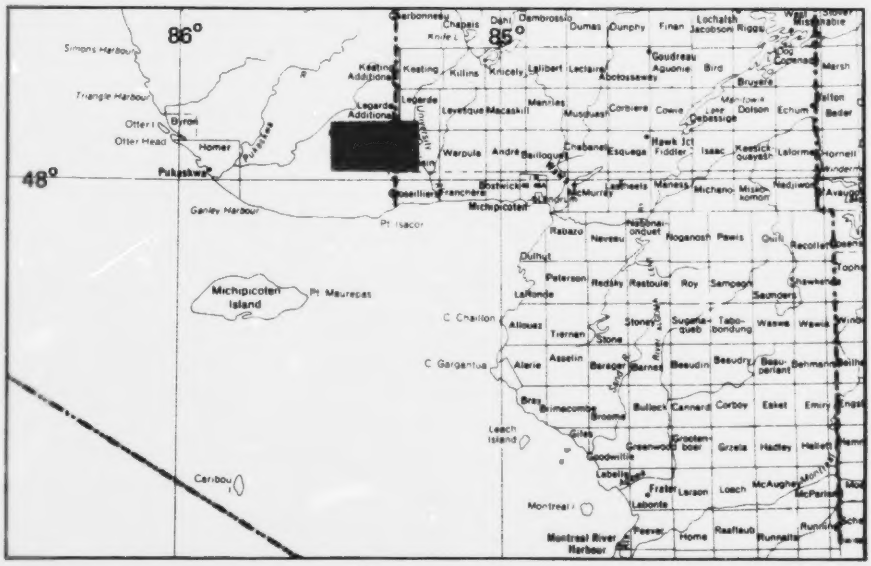
The purpose of the Mineral Deposits Section's component of the program is to document the mineralization types present in the belt, and their geological setting, with emphasis upon gold. In addition, this year the Mishibishu Deformation Zone (MDZ) was traced to the west and east of its previously known extent (Heather 1985), and detailed 1:2400 (1 inch to 200 feet) scale mapping of Muscocho Explorations Limited's Magnacon Property was initiated. Several other properties and showings were visited and mapped during the summer (Figure 059.1).

MINERAL EXPLORATION

Past exploration in the Mishibishu Lake Belt is summarized by Heather (1985) and by Bowen, Logothetis, and Heather (1986a, b, c, d, e). Exploration activity increased within the belt during the Summer of 1986 due to encouraging drill results from Muscocho Explorations Limited's Magnacon Property, and to the completion of a gravel road to that property to facilitate underground exploration, which improved access to the entire area. Muscocho Explorations Limited began work on a 1200-foot decline to test the main zone of gold mineralization (the Bandy Zone) at their Magnacon Property. They also continued a program of surface diamond drilling designed to better define existing mineralized zones and to test new zones.

During 1986, Granges Exploration Limited began a program of line cutting, soil sampling, and geophysics over their large property holdings, optioned from Macmillan Energy Corporation, to the west of Muscocho Explorations Limited and to the east of Mishi and Katzenbach Lakes (Figure 059.1). In addition, Granges Exploration Limited began a large diamond drill program to test both a gold mineralized zone intersected by Macmillan Energy Corporation during the Spring of 1986, and several geophysical anomalies.

During the Summer of 1986, Dominion Explorers Incorporated, a Durham Resources Incorporated Group company, drilled several shallow holes on their Missing Lake claims (Figure 059.1) and on their "Scuzzy Little Lake" Property (Figure 059.1). They also conducted limited soil sampling, V.L.F. electromagnetometer, and induced polarization surveys


86°
85°
48°
Simons Harbour
Triangle Harbour
Otter I.
Otter Head
Byron
Homer
Pukaskwa
Gargantua Harbour
Pt. Isacor
Michipicoten Island
Pt. Maureas
C. Chaillon
C. Gargantua
Leach Island
Caribou I.
Montreal I.
Montreal River Harbour
Michipicoten
Keating Addition
Legarde Addition
Keating
Killins
Kricely
Lalibert
Leclaire
Abotossaway
Levesque
Macaskill
Warpula
Andre
Bailloquet
Chabanel
Esquega
Fiddler
Isaac
Lalor
Hornell
Chapais
Dahl
Dambrossio
Dumas
Dunphy
Finan
Lochalsh
Jacobson
Riggs
Goudreau
Aguonie
Bird
Bruyere
Marsh
Corbiere
Cowie
Dolson
Echum
Hawk Jct
Bostwick
Lastheels
Maness
Michano
Rabazo
Nevaeu
Rabazo
Dulhut
Peterson
Redsky
Restoule
Roy
Sampson
LaRonde
Alloues
Tiernan
Stone
Stoney
Alerie
Asselin
Beaudin
Beaudry
Bray
Bullock
Cannard
Corboy
Esket
Emery
Giles
Greenwood
Grzela
Hadley
Goodwillie
Labonte
Fraser
Larson
Leach
McAughey
Peever
Home
Raaflaub
Runnalls

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

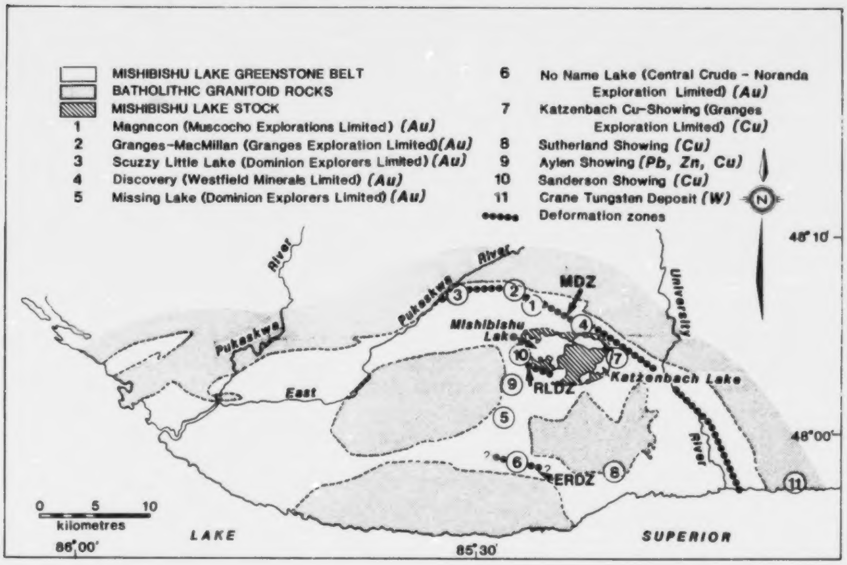

MISHIBISHU LAKE GREENSTONE BELT
BATHOLITHIC GRANITOID ROCKS
MISHIBISHU LAKE STOCK
1 Magnacon (Muscocho Explorations Limited) (Au)
2 Granges-MacMillan (Granges Exploration Limited)(Au)
3 Scuzzy Little Lake (Dominion Explorers Limited) (Au)
4 Discovery (Westfield Minerals Limited) (Au)
5 Missing Lake (Dominion Explorers Limited) (Au)
6 No Name Lake (Central Crude - Noranda Exploration Limited) (Au)
7 Katzenbach Cu-Showing (Granges Exploration Limited) (Cu)
8 Sutherland Showing (Cu)
9 Aylen Showing (Pb, Zn, Cu)
10 Sanderson Showing (Cu)
11 Crane Tungsten Deposit (W)
Deformation zones
N
48°10'
48°00'
River
River
Pukaskwa
Pukaskwa
East
MDZ
Mishibishu Lake
RLDZ
Katzenbach Lake
University
River
ERDZ
0 5 10
kilometres
86°00'
85°30'
LAKE
SUPERIOR

Figure 059.1. Mineral properties and showings visited in the Mishibishu Lake greenstone belt.

on the "Scuzzy Little Lake" Property. Several staking crews were observed working in the Mishibishu Lake belt during the field season.

GENERAL GEOLOGY

A description of the regional geology of the Mishibishu Lake belt is given by Bowen (this volume), and Bowen and Logothetis (1985).

STRUCTURAL GEOLOGY

A discussion of the regional structural geology can be found in Bowen (this volume). The majority of the supracrustal rocks in the Mishibishu Lake greenstone belt are weakly to moderately foliated. Several zones of intensely foliated rocks, which have partially or totally lost their primary textures, define complex, high strain zones, herein referred to as deformation zones. These deformation zones range in size from several metres to hundreds of metres in width, and up to tens of kilometres in length. Three of the larger and better defined deformation zones are the Mishibishu Deformation Zone (MDZ), the Rook Lake Deformation Zone (RLDZ), and the Eagle River Deformation Zone (ERDZ). All three zones are shown on Figure 059.1; to date, detailed structural analyses of the latter two zones have not been completed.

The Mishibishu Deformation Zone (MDZ) is a lithologically and structurally complex zone which hosts several gold showings (Figure 059.1). The MDZ is now known to extend from just west of Scuzzy Little Lake, eastward past Katzenbach Lake, a total distance of some 20 km (Figure 059.1). A zone of deformation also extends from just east of Katzenbach Lake, southeastward to Lake Superior (Figure 059.1). This latter zone may be contiguous with the MDZ, making the overall strike length of the deformation zone approximately 40 km. The majority of the deformation zones within the Mishibishu Lake greenstone belt appear to be localized along lithological contacts, particularly between volcanic and sedimentary rocks. The MDZ, and its southeastern extension, are localized along a major volcanic-sedimentary contact, possibly because of the competency contrast between these rock types. The MDZ varies in width from 200 m to 500 m and is composed of several anastomosing shear zones. It was defined for field mapping purposes as being an area where original rock textures are partially or totally destroyed by hydrothermal alteration and/or deformation, in strong contrast with the relatively less deformed rocks found regionally. Rocks to the north and south of the MDZ exhibit an increasing state of strain as the MDZ is approached, and become intensely strained in the central core. The MDZ is characterized by strong penetrative fabrics, a stretching lineation, asymmetric and symmetric chevron folds of the S^1 foliation, and conjugate sets of kink bands.

ECONOMIC GEOLOGY

1. MAGNACON GOLD PROPERTY

The Magnacon Property consists of 19 patented claims and several claim fractions which encompass the Mordaunt, Bandy (Main), Curtis, and Millard mineralized zones. A simplified 1:2400 scale map, showing the lithological and structural geology of an area covering the Bandy (Main), Curtis, and Millard Zones, is shown in Figure 059.2.

The Magnacon mineralized zones all occur within a 240 m wide core of intensely altered and deformed rocks within the MDZ (Figure 059.2). This core is flanked to the north by mafic to intermediate volcanic rocks and to the south by clastic sedimentary rocks.

Mafic to Intermediate Volcanic Rocks

The volcanic rocks to the north consist predominantly of massive to foliated mafic flows and sills composed of medium- to coarse-grained amphibole and feldspar, which may be secondary due to amphibolite grade metamorphism related to the Northern Batholith

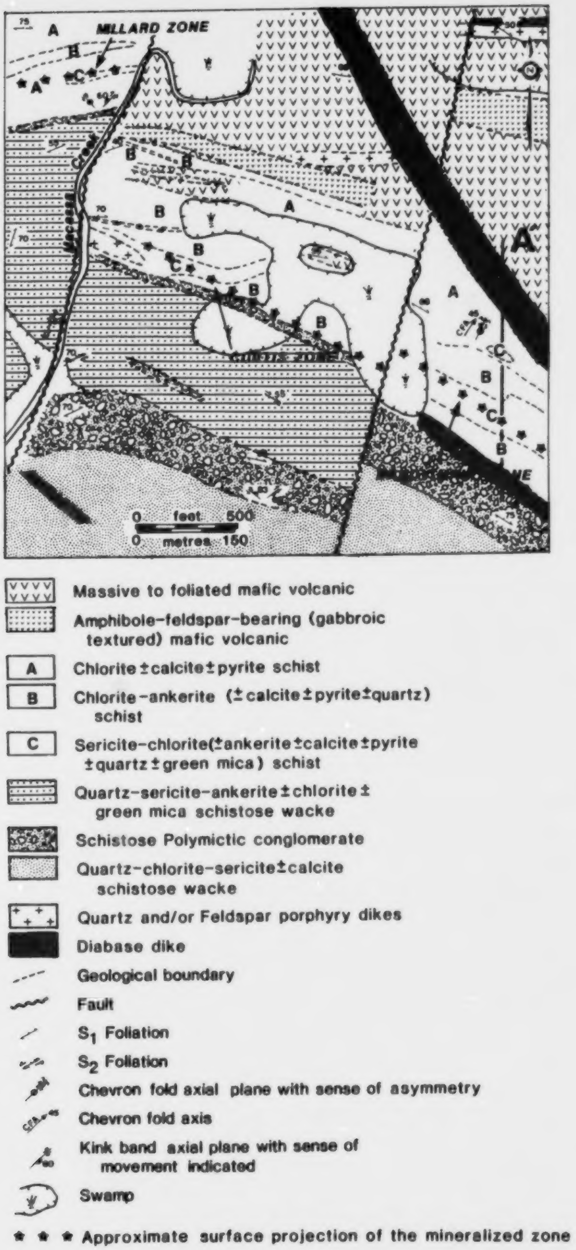

MILLARD ZONE
A
B
C
Magnacon Creek
feet 500
metres 150
Massive to foliated mafic volcanic
Amphibole-feldspar-bearing (gabbroic textured) mafic volcanic
A Chlorite ± calcite ± pyrite schist
B Chlorite-ankerite (± calcite ± pyrite ± quartz) schist
C Sericite-chlorite (± ankerite ± calcite ± pyrite ± quartz ± green mica) schist
Quartz-sericite-ankerite ± chlorite ± green mica schistose wacke
Schistose Polymictic conglomerate
Quartz-chlorite-sericite ± calcite schistose wacke
Quartz and/or Feldspar porphyry dikes
Diabase dike
Geological boundary
Fault
S1 Foliation
S2 Foliation
Chevron fold axial plane with sense of asymmetry
Chevron fold axis
Kink band axial plane with sense of movement indicated
Swamp
★ ★ ★ Approximate surface projection of the mineralized zone

Figure 059.2. *Simplified 1:2400 scale geological map of the Magnacon Property.*

(*see* Bowen, this volume). These mafic volcanic rocks become progressively more altered and strained as the central core of the MDZ is approached. Within the coarser flows and associated sills, the amphibole and plagioclase crystals become elongated and eventually are smeared out along the foliation planes, creating well foliated chlorite±calcite schists. The volume of these schists increases significantly toward the core of the MDZ (Figures 059.2 and 059.3).

Minor amounts of mafic to intermediate pyroclastic rocks are intercalated with the flows mentioned above. These pyroclastics consist of strongly deformed volcanic breccias and lapilli-tuffs which closely resemble those mapped north of the Northwest showing, some 3 km to the east.

Clastic Sedimentary Rocks

The sedimentary rocks to the south consist of interbedded polymictic and oligomictic conglomerates and wackes, which become progressively more altered and strained as the core of the MDZ is approached. A distinctive 2 to 5 m wide polymictic conglomerate horizon is the first clearly recognizable sedimentary rock south of the intensely altered and strained core (Figure 059.2). This horizon is granitoid clast-dominated and contains minor chert-magnetite iron formation clasts, while most of the mafic volcanic clasts are so smeared out that they are difficult to distinguish from the chloritic matrix. This particular conglomerate horizon is laterally extensive and has been traced over several kilometres. South of this narrow conglomerate horizon is a 50 to 60 m thick sequence of intercalated polymictic and oligomictic conglomerates (Figure 059.2). The polymictic conglomerates found within this sequence are distinguished from that described above by the presence of red jasperoidal iron formation clasts, and a higher percentage of mafic clasts. There are also oligomictic quartz granule to pebble conglomerates which contain up to 80 percent subrounded quartz clasts within a chloritic matrix. A distinctive wacke unit separates the granitoid clast-dominated polymictic conglomerate from the thicker conglomerate sequence to the south. This well foliated, gritty-textured wacke contains chloritic fragments and, locally, green mica fragments up to 3 cm in length. The green mica fragments are found in close proximity to the intensely altered and strained core of the MDZ. The origin of these chloritic and green mica fragments is not known. The granitoid clast-dominated conglomerate and the schistose wacke with chloritic and green mica fragments form the footwall to the mineralized zones (Figures 059.2 and 059.3).

Felsic Porphyry Dikes

Both quartz-feldspar porphyry (QFP) and feldspar porphyry (FP) dikes were recognized within the mafic volcanic rocks and the intensely altered and strained zone (Figure 059.2). A protracted history of porphyry dike emplacement is evident, as there are dikes with varying degrees of alteration and deformation ranging from weakly foliated, with porphyritic texture preserved, to intensely foliated quartz-sericite±hematite schists. The majority of these dikes appear to cut the regional foliation at approximately 5° to 10°, and range in width from 10 cm up to 15 m.

Some dikes are cut by mineralization while others are not, indicating that dike emplacement was broadly coeval with mineralization. Some of the feldspar porphyry dikes are texturally similar to those observed crosscutting the Mishibishu Lake Stock (MLS), a quartz monzonite to monzonite intrusion located 2 km to the south (Figure 059.1). Additional evidence to suggest a link between the MLS and the

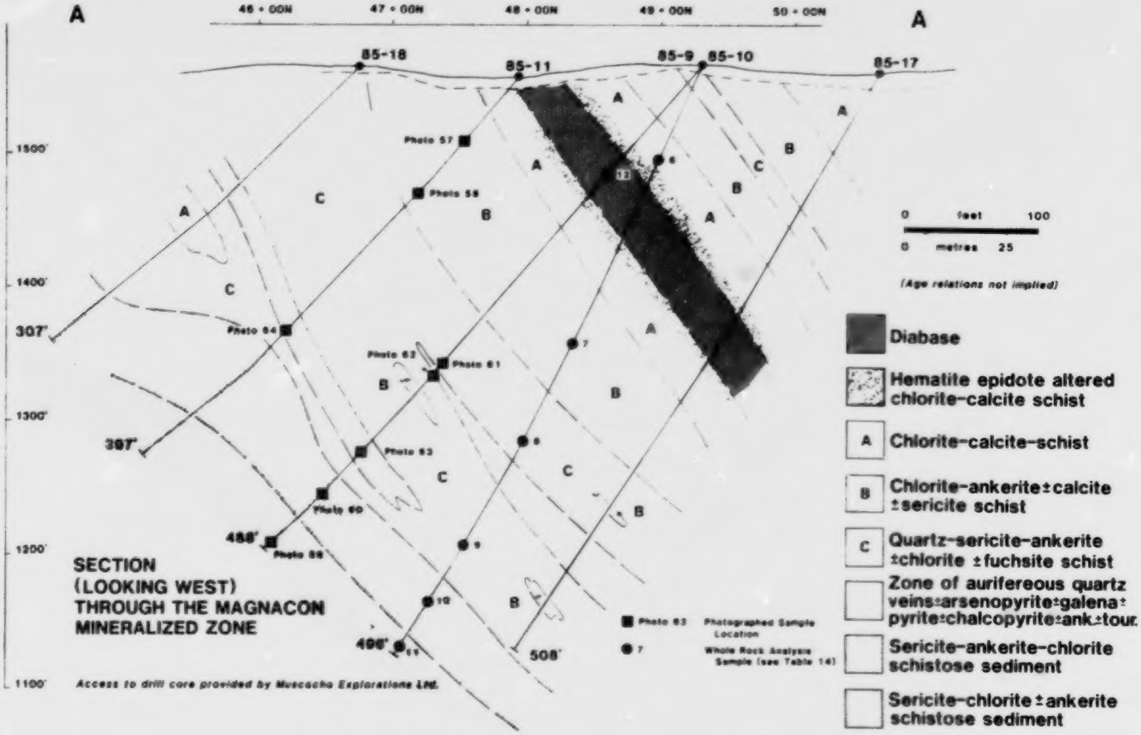

A
46 + 00N
47 + 00N
48 + 00N
49 + 00N
50 + 00N
A
85-18
85-11
85-9
85-10
85-17
1500'
1400'
1300'
1200'
1100'
307'
397'
488'
496'
508'
Photo 57
Photo 58
Photo 64
Photo 62
Photo 61
Photo 63
Photo 60
Photo 59
6
7
8
9
10
11
12
A
B
C
0 feet 100
0 metres 25
(Age relations not implied)
Diabase
Hematite epidote altered chlorite-calcite schist
A Chlorite-calcite-schist
B Chlorite-ankerite±calcite ±sericite schist
C Quartz-sericite-ankerite ±chlorite ±fuchsite schist
Zone of auriferous quartz veins±arsenopyrite±galena±pyrite±chalcopyrite±ank±tour.
Sericite-ankerite-chlorite schistose sediment
Sericite-chlorite±ankerite schistose sediment
Photo 63 Photographed Sample Location
7 Whole Rock Analysis Sample (see Table 14)
SECTION
(LOOKING WEST)
THROUGH THE MAGNACON
MINERALIZED ZONE
Access to drill core provided by Muscocho Explorations Ltd.

***Figure 059.3.** Cross-section, looking west, through the Bandy (Main) Zone. See Figure 059.2 for the location of the section A-A'. Photograph location and rock analysis numbers refer to those used in Heather (1986).*

QFP and FP dikes, found in the vicinity of the mineralization, are the distinctive specular hematite-filled joints and fractures found cutting the MLS and some of the aforementioned dikes. No porphyry dikes have been found to date within the sedimentary rocks immediately south of the intensely altered and strained zone on the Magnacon Property; however, they are present in similar sedimentary rocks further to the east. Samples of the MLS, an FP dike cutting the MLS, and a QFP dike from near the mineralized zone, were collected for U-Pb zircon age determination.

Intensely Altered and Strained Zone

Within the core of the MDZ, all primary rock textures have been totally destroyed by intense alteration and deformation. The mafic volcanic rocks are now represented by chlorite-calcite schists which grade into chlorite-ankerite (±sericite) schists toward the mineralized zones (Figures 059.2 and 059.3). The sedimentary rocks are now variable schists of quartz-sericite-chlorite (±ankerite±calcite), with the schists in proximity to the mineralized zones being more sericitic (Figures 059.2 and 059.3).

A distinctive quartz-sericite (±ankerite, ±green mica, ±chlorite) schist hosts the majority of the mineralization. This schist has both gradational and sharp contacts with the overlying and underlying schists.

Mineralization

Mineralization within the Bandy (Main), Curtis, and Millard Zones consists of auriferous quartz (±ankerite±arsenopyrite±pyrite±galena±chalc opyrite±tourmaline) veins, which form zones from several centimetres up to several metres in width. Individual veins vary in width from several centimetres up to several metres and in colour from bull-white to dark bluish grey. Gold occurs in its native state as fracture fillings in quartz veining, and associated with arsenopyrite. Locally, the sericitic wall rocks adjacent to the mineralized quartz veins contain abundant disseminated pyrite and arsenopyrite which have associated gold. The Bandy (Main) Zone has more galena associated with it than do the Curtis and Millard Zones, which have little or none. At the property scale, the Curtis and Bandy (Main) Zones cut obliquely across the general foliation trend within the MDZ at a low angle (Figure 059.2). The majority of the mineralized veins occur within quartz-sericite schists. A number of other zones within the intensely altered and strained portion of the MDZ contain anomalous gold values, as do several narrow high strain zones within the sheared sedimentary rocks to the south.

Structure

All of the mineralized zones occur within the highest strained portion of the MDZ. The regional foliation (S fabric) is between 300 and 310°, whereas within the

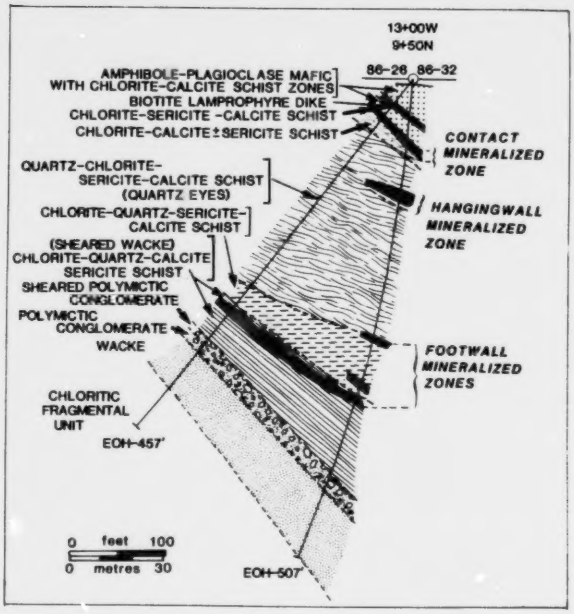

13+00W
9+50N
86-28
86-32
AMPHIBOLE-PLAGIOCLASE MAFIC WITH CHLORITE-CALCITE SCHIST ZONES
BIOTITE LAMPROPHYRE DIKE
CHLORITE-SERICITE -CALCITE SCHIST
CHLORITE-CALCITE±SERICITE SCHIST
QUARTZ-CHLORITE-SERICITE-CALCITE SCHIST (QUARTZ EYES)
CHLORITE-QUARTZ-SERICITE-CALCITE SCHIST
(SHEARED WACKE) CHLORITE-QUARTZ-CALCITE SERICITE SCHIST
SHEARED POLYMICTIC CONGLOMERATE
POLYMICTIC CONGLOMERATE
WACKE
CHLORITIC FRAGMENTAL UNIT
EOH-457'
EOH-507'
CONTACT MINERALIZED ZONE
HANGINGWALL MINERALIZED ZONE
FOOTWALL MINERALIZED ZONES
0 feet 100
0 metres 30

Figure 059.4. *Cross section, looking northwest, through the Granges-MacMillan Property.*

MDZ it becomes 280 to 290° (C fabric). Several cross structures, oriented between 335° and 025°, break the MDZ into panels (Figure 059.2). These cross structures are usually linear topographic depressions, occupied by swamps or creeks (e.g. Macassa Creek on Figure 059.2). Within these panels there are consistent geological and structural features, including specific rock types, such as conglomerate horizons or alteration assemblages, that can be traced continuously along strike (Figure 059.2). Small scale structural features, such as sense of movement on conjugate sets of kink bands, are consistent within individual panels, but differ within adjacent panels. A secondary (C') fabric is seen deforming an earlier foliation within the panels hosting the Curtis and Bandy (Main) mineralized zones (Figure 059.2). Both sinistral and dextral movements are indicated, while the movement indicated by regional foliation trajactories is sinistral. Both the Curtis and Bandy (Main) Zones are bounded by cross structures: the Curtis Zone by Macassa Creek to the west and a swamp-filled structure to the east, and the Bandy (Main) Zone by the same swamp-filled structure to the west and a large northwest-trending diabase dike to the east (Figure 059.2). Both the Curtis and Bandy (Main) Zones cut obliquely across the shear zone foliation (C fabric) at approximately 295 to 300°. Based on the apparent sinistral sense of shear indicated by regional foliation trajectories, the mineralized zones probably occupy shear fractures which developed late in the MDZ's history.

There is a strong, north-trending foliation developed within a 350 m wide zone located immediately west of Macassa Creek (Figure 059.2). Secondary, north-trending fabric development within this zone gives a sinistral sense of movement, but this contradicts evidence given by the apparent dextral offset across Macassa Creek of the granitoid, clast-dominated, polymictic conglomerate (Figure 059.2). The Macassa Creek Zone remains a complex area for which no conclusive interpretation can yet be made. To the west of this zone, the stratigraphy, the MDZ, and the mineralization appear to continue and into the Granges-MacMillan Property (Figure 059.1).

2. GRANGES-MACMILLAN GOLD PROPERTY

Located approximately 3 km northwest of Mishibishu Lake (Figure 059.1), the Granges-MacMillan Gold Property is within the Mishibishu Deformation Zone (MDZ), immediately west of Muscocho Explorations Limited's Magnacon Property. Granges Exploration Limited has outlined three zones of gold mineralization within a package of strongly sheared mafic volcanic rocks, quartz-feldspar porphyry(?), and clastic sedimentary rocks (Figure 059.4). The mafic volcanic rocks to the north form the hanging wall to the mineralization and consist of massive, medium- to coarse-grained, amphibole-plagioclase-bearing flows and sills, which are variably sheared to chlorite± calcite schists (Figure 059.4). Clastic sedimentary rocks to the south comprise the footwall and consist of interbedded polymictic conglomerates and fine- to coarse-grained wackes (Figure 059.4). Mafic volcanic rocks within the high strain zone are converted to chlorite-calcite schists while the sedimentary rocks become gritty quartz-chlorite-sericite-calcite schists. A 1.5 to 2.5 m wide mineralized zone, known as the "Contact Mineralized Zone" (E. Fluskey, Geologist, Granges Exploration Limited, Vancouver, personal communication, 1986) occurs at the contact of a foliated, "gabbroic-looking" amphibole-plagioclase mafic volcanic rock and a chlorite-sericite-calcite schist (Figure 059.4). A second mineralized zone, known as the "Hanging wall Mineralized Zone" (E. Fluskey, personal communication, 1986), occurs within a gritty-textured, chlorite-quartz-calcite schist containing variable amounts of sericite (Figure 059.4). The more sericitic portions host zones of narrow, smokey quartz veins with ankerite, arsenopyrite, and pyrite, and visible gold.

The lower Footwall Zone appears to be a sheared and altered wacke which, progressing southward out of the high strain zone, becomes a coarse wacke and a granitoid clast-dominated polymictic conglomerate. This footwall conglomerate is identical to the one in the footwall of Muscocho Exploration Limited's Magnacon Property to the east. Structurally below the conglomerate is a distinctive grey, gritty unit with angular chloritic (possibly with minor biotite) fragments up to 4 cm long (Figure 059.4). This rock resembles the chlorite-green mica fragmental rock in the Magnacon footwall, and may be an intermediate pyroclastic rock or a coarse wacke (?).

Both the Hanging Wall and Footwall Mineralized Zones are characterized by quartz (±arsenopyrite± pyrite±ankerite±tourmaline) veins with sericitic haloes. The Contact Mineralized Zone is related to a zone of disseminated pyrite and minor quartz veining within the chlorite-sericite-calcite schist.

The Granges-MacMillan mineralization has similarities to the Millard Zone mineralization, 450 m to the east, on the western side of Macassa Creek (Figure 059.2).

3. SCUZZY LITTLE LAKE GOLD PROPERTY

The Scuzzy Little Lake Gold Property is located 7.5 km northeast of Mishibishu Lake (Figure 059.1), within the western extension of the Mishibishu Deformation Zone (MDZ). Regional 1:15 840 scale mapping by the author has shown the MDZ to extend onto the Scuzzy Little Lake Property, where it is about 150 m wide and localized between mafic to intermediate, and possibly minor felsic, volcanic rocks to the north and clastic sedimentary rocks to the south.

The volcanic rocks to the north are amphibolitized, massive, mafic to intermediate flows with narrow intercalations of felsic volcanic rocks (?). The sedimentary rocks to the south are a series of polymictic conglomerate horizons within a sequence of quartz grit sandstones and dirty wackes. Within the MDZ, the mafic volcanic rocks are well foliated, chlorite-calcite schists, while the sedimentary rocks are gritty, quartz-chlorite (±sericite) schists. A 1 to 2 m wide polymictic conglomerate horizon within the southern portion of the MDZ contains highly deformed and rotated granitic clasts and minor chert-magnetite clasts within a chloritic matrix. This conglomerate horizon is almost identical to the conglomerate horizons found within the immediate footwall rocks of the Granges and Magnacon mineralized zones. The degree of alteration and deformation within the MDZ at the Scuzzy Little Lake Property is less than that seen within the MDZ north of Mishibishu Lake.

The gold mineralization at Scuzzy Little Lake is associated with a 2 to 3 m wide zone of quartz veining within a highly strained, well foliated, siliceous, dark grey to black rock. Away from the strained zone, the host rock is massive and contains occasional bluish quartz eyes and may be an intermediate volcanic rock or a wacke(?). The quartz veins associated with the gold mineralization vary in width from 1 to 10 cm and are subparallel to the foliation. Coarse disseminated arsenopyrite crystals, up to 0.5 cm in diameter, occur as 3 to 4 cm wide haloes about the quartz veins. The quartz veins are barren of sulphide mineralization but locally contain visible gold. This zone of mineralized quartz veins has been traced on surface along a strike distance of at least 100 m. Regional 1:15 840 scale mapping by the author has traced the grey, siliceous, quartz eye-bearing host rock over a strike length of 670 m to the west; however, no quartz veining or arsenopyrite mineralization was observed. Grab samples of quartz vein material, arsenopyrite-rich wallrock, and unmineralized country rock were taken by the author for assay (for Au, Ag, As, Pb, Zn, and Cu). Dominion Explorers Limited is currently diamond drilling this showing and other areas on the property.

4. DISCOVERY GOLD PROPERTY

The Discovery Property is located 700 m north of Mishi Lake (Figure 059.1) within a shear zone on the northern margin of the Mishibishu Deformation Zone. During 1986, mapping in the vicinity of an auriferous, galena-bearing quartz vein adjacent to a deformed diabase dike (Heather 1985) was continued. In addition, Jerry Ho, an undergraduate student at the University of Toronto, commenced a study of the Discovery Property as part of a B.Sc. thesis. Westfield Minerals Limited still holds this property but performed no work on it during the Summer of 1986.

5. MISSING LAKE GOLD SHOWINGS

The Missing Lake gold showings are located 2 km southwest of Mishibishu Lake (Figure 059.1). Several types of gold-anomalous mineralization occur at Missing Lake: (1) quartz-filled fault breccia, (2) disseminated and/or banded pyrite-carbonate rock, (3) quartz veins, and (4) recrystallized and sulphidized chert-magnetite iron formation with 3-5% pyrrhotite occurring along fractures and bedding planes. Dominion Explorers Limited is currently drilling several of these anomalous areas.

6. NO NAME LAKE GOLD SHOWING

The No Name Lake gold showing is located 10 km south of Mishibishu Lake (Figure 059.1). A program of stripping, trenching, and channel sampling was performed by Central Crude Limited during 1984, which led to the discovery of gold mineralization. Gold occurs in quartz veins associated with 1 to 5 m wide shear zones, which are localized at lithological contacts between medium-grained mafic volcanic rocks and intermediate volcanic flow and pyroclastic rocks. The mafic volcanic rocks are massive, gabbroic-textured amphibole-feldspar rocks, which may be coarse flows or synvolcanic sills. The intermediate volcanic rocks range from feldspar-phyric flows to lapilli-tuffs and volcanic breccias. As the shear zones are approached, the primary rock textures are obliterated and the mafic volcanic rocks become chlorite-calcite schists, while the intermediate volcanic rocks become sericite-quartz schists. Strong foliation developed within these shears is locally accompanied by a weaker second foliation and a conjugate set of kink bands. Pyrite and pyrrhotite are commonly found along foliation surfaces of rocks within the shear zones. Locally, these sulphide-rich shear zones are anomalous in gold, according to Central Crude Limited's channel sampling (Unpublished Company Report 1984, Central Crude Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto).

Three significant gold assays (0.408, 0.319, and 0.744 ounces gold per ton) were obtained from grab samples of quartz vein material collected by Central Crude Limited (Unpublished Company Report 1984, Central Crude Limited, Assessment Files Research vein occurs in a 2 m wide shear, localized between a medium-grained amphibole-feldspar-bearing mafic volcanic rock and an intermediate pyroclastic. The shear zone is extremely schistose and is highly silicified and sericitized. Within the central portion of the shear zone is a rusty weathering, 30 to 40 cm wide, white quartz vein with minor pyrite. The vein pinches and swells along strike. Its strike length could not be determined due to overburden cover. Several grab samples of vein material and other shear zone rocks in the area were collected for assay (for Au, Ag, As, Pb, Zn, and Cu) by Ontario Geological Survey field crews. Noranda Explorations

Limited has an option on this showing and is currently evaluating it.

7. KATZENBACH LAKE COPPER SHOWING

Located on the northeastern shore of Katzenbach Lake (Figure 059.1) is an altered quartz monzonite dike, related to the Mishibishu Lake stock. The dike is cut by numerous quartz (±pyrite±chalcopyrite) stringers. The showing was originally discovered in the late 1930s by Erie Canadian Mines Limited. Mapping in 1986 has shown that the copper mineralization is restricted to a 25 cm wide quartz vein located at the contact of a sericite-altered porphyry dike and a chlorite-calcite schist.

A strong, joint-controlled quartz vein stockwork exists within the porphyry and, to a lesser degree, in the surrounding schists, but most of this stockwork appears to be unmineralized. The exposed mineralized area is approximately 10 m long by 5 m wide. The schistose chlorite-calcite country rocks appear to be highly sheared mafic volcanic rocks from within the Mishibishu Deformation Zone, while the porphyry dike resembles an altered quartz monzonite and is somewhat less deformed. A grab sample of chalcopyrite-bearing quartz vein material collected in 1985 by an Ontario Geological Survey field crew assayed 2440 ppm Cu and 150 ppb Au. Additional sampling of this occurrence by the Ontario Geological Survey was performed during 1986. A sample of chalcopyrite-bearing quartz vein assayed 5000 ppm Cu, 21 ppb Au, <2 ppm Ag, <10 ppm Pb, <5 ppm Zn, and <1 ppm As. Another quartz vein assayed 12 ppm Cu, 2 ppb Au, <2 ppm Ag, <10 ppm Pb, 23 ppm Zn, and 5 ppm As.

8. SUTHERLAND COPPER SHOWING

The Sutherland copper showing is located on the western boundary line of Groseilliers Township, approximately 2.7 km north of Lake Superior (Figure 059.1). Access to the showing is by helicopter only. W.D. Sutherland and Associates diamond drilled 14 holes totaling 1699 m (5149 feet) on the showing in 1965. Mapping of this showing by the author at 1:15 840 scale revealed a narrow zone of strongly foliated and locally kinked mafic volcanic and sedimentary rocks within the southern portion of the Bowman Lake Batholith along a steep-sided, narrow valley. Mineralization occurs for 600 m (2000 feet) along a steeply dipping, north-striking shear zone which is coincident with a regional lineament. The strongly sheared zone is up to 30 m wide and consists of a complex of quartz veins within dark green chlorite schist and silicified sericite schists. Quartz veining and shearing extend an undetermined distance into the granite on either side of the schistose supracrustals. Locally, chlorite and quartz-sericite schists form a *lit-par-lit* texture which may represent a sheared migmatite zone.

The only mineralization observed on surface in the current Ontario Geological Survey investigation was a 1 m wide band of massive black magnetite with clots and smears of chalcopyrite, pyrite, and possibly pyrrhotite, hosted within a 2 m wide sheared wacke which is flanked on either side by silicified and quartz-stockworked granite. Bennett and Thurston (1977) and Sutherland's drill logs (Unpublished Company Report, 1965, Sutherland and Associates Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto) describe the mineralization as consisting predominantly of disseminated grains and blebs of pyrite and chalcopyrite within quartz veins in silicified granite and mafic schists. Several rusty quartz veins and representative samples of the sheared host rocks were taken for assay (for Au, Ag, As, Pb, Zn, and Cu).

9. AYLEN SHOWING

The Aylen showing is located 3.6 km southwest of Mishibishu Lake on the Floatingheart River (Figure 059.1). Prospected and drilled in the early 1950s by Aylen Mines Limited, the Aylen showing consists of a 6 m wide by 9 m long zone of quartz veining. The mineralization consists of chalcopyrite, pyrite, sphalerite, galena, fluorite, and pyrrhotite in quartz veins which exhibit open-space filling and contain brecciated wall rock near their margins. The host rocks are highly silicified wackes which are foliated and locally kinked. A 3 to 4 m wide, north-trending diabase dike flanks the veins to the east. This diabase becomes foliated toward the vein structure and is cut by calcite±galena veinlets. Several grab samples of the mineralized veins, silicified wackes, and deformed diabase were collected for assay (for Au, Ag, As, Cu, Zn, and Pb).

10. SANDERSON SHOWING

The Sanderson showing is located on a small point on the extreme southwestern corner of Mishibishu Lake (Figure 059.1). The showing was originally found by C.D. Sanderson in the 1950s, while employed by Aylen Mines Limited. During the early 1980s, Sanderson completed some additional trenching on the quartz (±pyrite±chalcopyrite) vein system. Mapping during 1986 by the author has shown the mineralization to be related to a bull-white quartz vein system which exhibits vuggy open-space quartz crystal development and brecciated wall rock at the vein margins. The vein system is 1 to 2 m wide and has been found along a strike distance of some 75 m to the northwest. The host rock is a foliated and weakly silicified, fine-grained wacke, which is cut by a 1 m wide feldspar porphyry dike located 1 m east of the vein. A narrow, northwest-trending porphyritic diabase dike cuts the wackes and subparallels the quartz vein system 1 to 5 m to the west. In the northernmost trench exposure, the quartz veins are within the feldspar porphyry, which is cut by the diabase dike. Several grab samples of vein material were collected for assay (for Au, Ag, As, Pb, Zn, and Cu). The feldspar porphyry dikes are similar to those seen elsewhere associated with the Mishibishu Lake stock, and may be related to it.

11. THE CRANE TUNGSTEN DEPOSIT

Since the original discovery of tungsten mineralization on the northern shore of Lake Superior by a Mr. Fenlon in the early 1940s, this occurrence has been known by various names, including the Fenlon Scheelite Property, the Michipicoten Tungsten Deposit, and the Crane Tungsten Deposit. Located 10 km east of Dog Harbour (Figure 059.1), the Crane Deposit consists of scheelite-bearing quartz veins hosted in an enclave of schistose conglomerates (Dore?) bounded by massive granodiorite. The mineralized zone is about 9 m wide and extends 400 m to the northwest from the shore of Lake Superior. Selected grab samples of vein material were taken for assay (for Au, Ag, As, Pb, Zn, Cu, and W). Detailed accounts and maps of the showing can be found in Bennett and Thurston (1977) and Nickel (Unpublished Company Report 1952, Crane Company Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto).

DISCUSSION

Several features within the Mishibishu Lake greenstone belt have a spatial and possible temporal relationship with all of the known gold showings. To date, all nine of the gold showings are within zones of high strain (Figure 059.1), with the Mishibishu Deformation Zone (MDZ) hosting seven. These high-strain zones are commonly localized at lithological contacts (e.g. volcanic-sediment) due to the competency contrast between lithologies, which focused the stress created during tectonism. The MDZ may have developed because of the emplacement of the large Pukaskwa Gneiss Complex to the north.

Within a 7 km long section of the MDZ, immediately north of the Mishibishu Lake Stock, are located six gold showings within large zones of intense hydrothermal alteration. Quartz-feldspar and feldspar porphyry dikes, texturally similar to those associated with the Mishibishu Lake Stock, are seen being cut by, and cutting, the gold mineralization in several of the showings. There is, therefore, a spatial, and possibly a temporal, relationship between the Mishibishu Lake Stock and the intense hydrothermal alteration, porphyry dikes, and gold mineralization found within the MDZ.

A relatively systematic pattern of alteration flanks several of the gold showings within the MDZ. In order of increasing proximity to the auriferous zone, the predominant alteration types are: a) chlorite-calcite, b) chlorite-ankerite, c) chlorite-sericite, and d) sericite-quartz schists. The contacts between these alteration types are gradational. This alteration zonation is manifested best within the mafic volcanic rocks, and is more cryptic and irregular in the sedimentary rocks. The gold-bearing zones occur within the sericite-quartz schists as vein complexes which appear to cut the foliation at a low angle, indicating that they occupy a brittle fracture (e.g. a shear fracture) which developed late in the shear zone's history.

RECOMMENDATIONS

Gold exploration within the Mishibishu Lake greenstone belt is still in its infancy, with large tracts of ground still to be adequately prospected. Several high-strain zones, such as the southeastern extension of the MDZ, the Rook Lake Deformation Zone, and the Eagle River Deformation Zone, offer excellent potential for gold exploration. Locating areas of coincident deformation and hydrothermal alteration is extremely important in locating mineralization in the belt. For rocks within greenschist facies regional metamorphism, the alteration is manifested as intense carbonatization (e.g. calcite and ankerite) and sericitization. In rocks within amphibolite facies regional metamorphism, the carbonatization is not present, but garnet, staurolite, and biotite may reflect the alteration. To date, all of the known gold occurrences have been found in greenschist facies rocks, or within greenschist retrograded, amphibolite facies rocks (e.g. Scuzzy Little Lake Gold Property).

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060. Geology of Banting Township and the Western Part of Best Township, District of Nipissing

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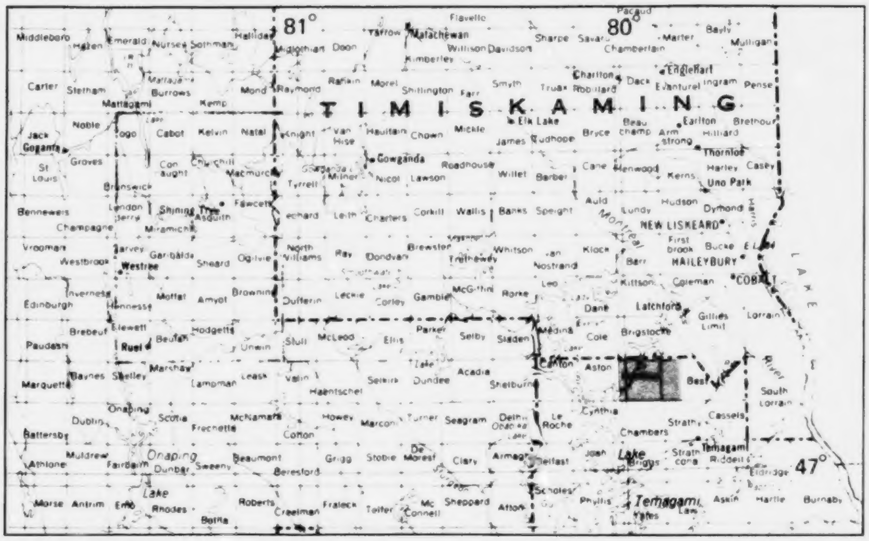
INTRODUCTION

Detailed mapping and sampling of Banting Township and the western part of Best Township were carried out in 1986 at a scale of 1:7920 (1 inch to 660 feet). This project represents an extension of an earlier investigation of a narrow volcanic inlier situated in the McLean Lake-Lundy Lake area (Owsiacki 1983, 1984). The study area includes all of Banting Township and the adjacent western part of Best Township, bounded by Latitudes 47°08′45″N and 47°14′05″N and Longitudes 79°51′00″W and 80°01′06″W, an area of approximately 80 km². The focus of this study has been to trace extensions of metavolcanic units from the McLean Lake-Lundy Lake area, and to investigate the nature of the contact zone between these metavolcanics and granitic intrusions, as well as determining the base and precious metal potential of these rocks.

GENERAL GEOLOGY

The oldest rocks exposed comprise steeply-dipping, Archean, intermediate, heterolithic tuff-breccia, mafic volcanic flows, and monolithic rhyolite breccia. These units are confined, for the most part, to a single, branching belt located in the central portion of the study area. Narrow extensions of this belt and other smaller, discrete volcanic units are exposed in both the southeastern and southwestern parts of the area. While these rocks are petrologically similar to those described in the main belt (Owsiacki 1984), their distribution is more discontinuous, particularly in zones bordering the enclosing granitic rocks. Moreover, textural and mineralogical variations indicate that assimilation of the metavolcanics in specific zones, during granitoid emplacement, was significant. Many of the original structures and textures have been destroyed by this assimilation, making identification of the precursor difficult. These metavolcanics are typically metamorphosed from greenschist to amphibolite facies and comprise varying proportions of chlorite, amphibole, and biotite. They are also commonly incorporated within a granite migmatite which is developed locally. Schistosity is best developed in tuffaceous rocks in which fragments range from lapilli to bomb size. These fragments commonly exhibit strain textures and are elongate parallel to the foliation. This is best illustrated within mafic lapilli-tuff and tuff-breccias containing essential white rhyolite pyroclasts. Foliation is extremely variable (even on an outcrop scale) and tends to parallel contacts with the granitic rocks. Com-


81°
80°
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TIMISKAMING
Middleboro
Hazen
Emerald
Nursey
Sothman
Halliday
Mond
Raymond
Matachewan
Flavelle
Sharpe
Savard
Pacaud
Chamberlain
Marter
Bayly
Mulligan
Willison
Davidson
Kimberley
Carter
Stetham
Burrows
Mattagami
Kemp
Rafilain
Morel
Shillington
Farr
Smyth
Truax
Robillard
Charlton
Dack
Evanturel
Englehart
Ingram
Pense
Noble
Togo
Cabot
Kelvin
Natal
Knight
Van Hise
Haultain
Chown
Mickle
Elk Lake
James
Tudhope
Bryce
Beauchamp
Armstrong
Earlton
Bethour
Hilliard
Thornloe
Jack
Gogama
Groves
St Louis
Connaught
Churchill
Macmurchy
Gowganda
Tyrrell
Milner
Nicol
Lawson
Roadhouse
Willet
Barber
Cane
Henwood
Kerns
Harley
Casey
Uno Park
Brunswick
Benneweis
London
Jerry
Shining Tree
Asquith
Fawcett
Leith
Charters
Corkill
Wallis
Banks
Speight
Auld
Lundy
Hudson
Dymond
Montreal
NEW LISKEARD
Champagne
Miramichi
Vrooman
Westbrook
Garvey
Westree
Garibaldi
Sheard
Ogilvie
North Williams
Ray
Donovan
Brewster
Tretheway
Whitson
Van Nostrand
Klock
Barr
Firstbrook
Bucke
HAILEYBURY
COBALT
Inverness
Edinburgh
Hennessy
Moffat
Amyot
Browning
Dufferin
Leckie
Corley
Gamble
McGiffin
Rorke
Leo
Kittson
Coleman
Dane
Latchford
Gillies Limit
Lorrain
Brebeuf
Blewett
Paudash
Ruel
Beulah
Hodgetts
Unwin
Stull
McLeod
Ellis
Parker
Selby
Sladen
Medina
Cole
Brigstocke
Baynes
Shelley
Marquette
Marshay
Lampman
Leask
Valin
Haentschel
Selkirk
Dundee
Acadia
Shelburne
Canton
Aston
Best
South Lorrain
Onaping
Dublin
Scotia
McNamara
Frechette
Howey
Marconi
Turner
Seagram
Delhi
Le Roche
Cynthia
Chambers
Strathy
Cassels
Battersby
Cotton
Muldrew
Athlone
Fairbairn
Onaping
Dunbar
Sweeny
Beaumont
Beresford
Grigg
Stobie
De Morest
Clary
Armagh
Belfast
Joan
Lake
Briggs
Strathcona
Temagami
Riddell
Eldridge
Lake
Morse
Antrim
Emo
Rhodes
Botha
Roberts
Creelman
Fraleck
Telfer
Mc Connell
Sheppard
Afton
Scholes
Phyllis
Temagami
Yates
Askin
Hartle
Burnaby

LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles

positional banding in tuffaceous units is primary in most instances, but occasionally develops as the result of increased strain and coalescence of deformed fragments.

Outcrops of the metavolcanic units are commonly separated, from each other by granitic bodies. This pattern most likely represents roof pendant development near the top of the intrusion. Contacts are generally sharp, highly irregular, and form as narrow, subparallel, intercalations of volcanic and granitic material. The shape of the volcanic bodies is dictated by a variety of factors, including the degree of brecciation, and assimilation of the volcanic xenoliths within the granitic intrusion. The degree of granite veining and diking in the volcanic units increases toward the contacts with the surrounding granite. This is accompanied by an increase in both the intensity and degree of brecciation, rafting, and alteration of the enclosed volcanic rocks. Passive block-stoping of the metavolcanics during granite emplacement has resulted in the development of agmatitic structures similar to those described from migmatitic rocks in the Maple Mountain Area (Card *et al.* 1973).

The metavolcanics have been intruded by an Archean mafic to ultramafic body, described previously as an amphibolite in the field (Owsiacki 1984). This unit generally occupies the contact between the volcanic and granitic rocks in the southern portion of the study area. Most of this body more closely resembles a hornblende gabbro and is characterized by a coarse-grained texture, distinct mottled appearance, and well developed foliation. In some places, grain size is diminished and the rock, described as hornblendite, may contain up to 25 percent disseminated magnetite and resemble an ultramafic extrusive rock. Occasionally, volcanic xenoliths have been incorporated within the coarse-grained hornblende gabbro. In isolated zones, the unit is veined by granite and is incorporated in migmatite. Despite the development of a highly variable foliation in the contact zones, which is suggestive of plastic deformation, alteration is apparently less severe than that experienced by the volcanic rocks. Agmatitic textures are commonly developed in some areas where sharply bounded, angular blocks of coarse-grained hornblende gabbro and fine-grained hornblendite occur together with granite.

Granitic rocks underlie much of the study area. Although compositional and textural variations exist on a local scale, the predominant mineralogy and texture most closely reflect an equigranular quartz monzonite. Card *et al.* (1973) noted that granitic bodies elsewhere in the area form as discrete plutons, 6.5 to 13 km in diameter, whose margins are delineated by narrow metavolcanic belts and/or migmatitic zones. The granitic rocks of the southern portion of the study area comprise the northern part of the Chambers-Strathy Batholith (Bennett 1978). Zones of extensive migmatization extend along the southern margin of the main volcanic belt and along the northern boundary of Banting Township, close to Anima-Nipissing and Mannajigama Lakes.

Crosscutting veins and dikes form a minor constituent of the various granitic bodies. Compositions and textures of these younger intrusive phases range from quartz diorite to aplite and pegmatite. The presence of these units attests to a complex felsic intrusive history. This is best illustrated at the batholith margins, where extensive interaction with pre-existing volcanic and ultramafic intrusive rocks has taken place.

Quartz diorite appears to be the earliest phase of the felsic intrusive sequence and may possibly represent contamination from assimilation of volcanic units. It is distinguished by a mottled, fine-grained, "salt and pepper" appearance, produced by a high mafic mineral content, plagioclase, and subordinate quartz. This rock is commonly foliated and in places is intruded by nonfoliated, pink or grey quartz monzonite.

Granitic migmatites, megascopically composite rocks that consist of distinct neosome and metamorphic paleosome components (Mehnert 1971), apparently formed throughout the entire felsic intrusive history of this area. The majority of migmatites are characterized by relatively minor assimilation, alteration, and/or partial melting of the paleosome. Agmatic (breccia), schollen (raft), and phlebitic (vein) structures predominate in these rocks, in which aplite, pegmatite, or quartz monzonite form the leucosome. However, other metatectic migmatites are typically more strongly deformed and are distinguished by stromatic (layered), schlieric, ptygmatic, and nebulitic structures. Brecciation and migmatization are believed to have been repeated processes in the formation of these rocks. Isolated occurrences of heterolithic migmatite, including metavolcanic, ultramafic intrusive, and felsic intrusive paleosome components on an outcrop scale, are illustrative of the high degree of scavenging and mixing that has occurred. Extensive assimilation and the production of contaminated phases are apparently minimal and restricted to a local scale. Consequently, the massive granitic rocks are fairly homogeneous and lack a significant heterogeneous, "gneissic" halo, as described for granites in the Lake Abitibi Batholith (Jensen and Langford 1985), except in a few isolated instances. However, rocks from this area do exhibit foliations that are commonly sub-parallel to batholith contacts with volcanic rocks. Xenoliths are frequently aligned in the direction of foliation, suggesting that brecciation, migmatization, and deformation were penecontemporaneous and took place during the emplacement of the batholith. Although deformation in the granitic rocks decreases toward the centre of the batholith, both linear and arcuate zones of well foliated and mylonitic rocks are developed in isolated localities. These narrow zones may represent faults or areas in which shallower levels of erosion have preserved the upper, more foliated, levels of the intrusion.

The intrusion of lamprophyre dikes, minor mafic feldspar porphyry dikes, and pyroxenite stocks reflects late Archean magmatic activity in the study area. The pyroxenite and mafic feldspar porphyry are exposed in only a few locations. Lamprophyre dikes occur primarily within granitic rocks where they can be traced for several hundred metres. The dikes vary in width from 2 to 30 m and commonly pinch and swell. They more infrequently occur as composite bodies where they contain stoped, tabular, granitic xenoliths. Smaller granitic and lamprophyric xenoliths are common and are subrounded to ovoid in shape, indicating *in situ* milling of the fragments.

The Coleman Member of the lower Gowganda Formation (Huronian Supergroup) unconformably overlies the Archean basement and represents the only Proterozoic sedimentary rock in the area. The facies of the Gowganda Formation in the Cobalt camp have most recently been described by Mustard (1985) and have been compared to those in this study area. The rocks occupy a narrow trough that extends northeastward from Red Squirrel Lake, and bifurcates northward and northeastward through Anima-Nipissing and Gilbert Lakes, respectively. A small outlier is also exposed along the southern and southwestern shores of Whitewater Lake. The unconformity is exposed in several locations and typically reflects a very irregular paleotopography. Basal breccia is found in a number of locations and is composed of angular fragments of subjacent granitic and volcanic rocks. The bedded sedimentary rocks usually dip gently, at angles seldom exceeding 10°. In the southwestern part of the map area, these rocks consistently dip toward the west.

The predominant Coleman Member lithofacies includes diamictite, sandstone, and mudstone. All have limited lateral continuity and are laterally juxtaposed and complexly interbedded. Diamictite, which represents a poorly sorted admixture of mud, sand, and gravel, invariably occupies the basal portion of the sedimentary sequence. It also occurs at stratigraphically higher levels, together with bedded sandstone and mudstone. Although clast composition and size vary greatly within the diamictite, an increase in the degree of sorting commonly results in the development of local stratification, graded bedding and cobble, ortho-, and paraconglomerate.

Thin- to medium-bedded and interbedded sandstone and mudstone comprise the bulk of the sedimentary sequence. Sandstone is commonly pebbly (>5% gravel) and massive, lacking primary sedimentary structures. Where interbedded with mudstone, it may form lenticular beds which are commonly crossbedded. This crossbedding defines a paleocurrent flow from the north or northeast.

Mudstone is generally thickly laminated or very thinly bedded. It also exhibits few primary structures except where rhythmically laminated. Convolute bedding is commonly observed in the thicker units. More massive units are believed to represent a distal marine depositional environment. Dropstones, characteristic of the Coleman Member, are found in all of these units and are attributed to the melt-out of ice-rafted debris.

A gently undulating sill of Nipissing Diabase dominates much of the map area and forms an eroded arch in which the western limb occurs as an arcuate body extending from the northwest through to the central and south-central portions of the study area with westerly dips of 10° to 15°. The diabase appears more irregular in the eastern part of the area due to topographic effects and steeper undulations in the eastern limb of the sill. There is also a suggestion in this area of the presence of more than one sill. Zoning, typical of differentiated Nipissing Diabase described by Hriskevich (1952) in the Cobalt area, also is developed here. The upper and lower contacts of the sill are characterized by massive, fine-grained quartz diabase. The upper half of the sill commonly exhibits a clotty or varied texture, formed by coarse-grained to pegmatitic patches of diabase within a medium-grained, subophitic matrix. Miarolitic cavities and pegmatite veins occur near the top of the sill. The lower half of the sill usually consists of massive, fine- to medium-grained hypersthene diabase.

Fine-grained, northwesterly and northeasterly trending diabase dikes intrude both the Coleman Member sedimentary rocks and the Nipissing Diabase. Although only the northwesterly trending dikes are observed crosscutting the Nipissing Diabase, it is assumed that the northeasterly trending dikes intrude the diabase as well, but this is not as readily distinguishable. The dikes are typically 1 to 50 m wide and contain small plagioclase phenocrysts (<1 mm in size) which occur in clusters, producing a glomeroporphyritic texture. Larger dikes are locally porphyritic with 1 to 3 cm plagioclase phenocrysts. Small felsite dikes are less common and are erratically distributed.

An olivine diabase dike of the Sudbury swarm, previously described by Card and Lumbers (1977), Bennett (1978), and Owsiacki (1984), was traced along a continuous northwesterly trend through the study area. It is characteristically coarse grained, highly magnetic, and weathers to rounded, gossany outcrop. It represents the youngest Precambrian rock in the area and shows no evidence of deformation or later significant faulting.

All Archean rocks have undergone varying degrees of deformation; however, it is most prevalent and best developed within the metavolcanics. Isoclinal folding, with accompanying strain fabrics and axial planar foliation, is widespread. Structural fabrics commonly parallel the margins of the volcanic belts, except where the intrusion of felsic rocks has superimposed new fabrics and disrupted pre-existing structural elements. Proterozoic rocks have apparently undergone little deformation, although homoclinal sedimentary sequences in Coleman Member rocks indicate broad regional subsidence and uplift. Rare kink bands have also been observed in these rocks.

ECONOMIC GEOLOGY

As noted previously by Owsiacki (1984), evidence for the formation of silver-arsenide vein-type deposits, similar to those at Cobalt, is almost entirely lacking in the study area, despite the fact that rock types and structural relationships are similar. Veins composed predominantly of carbonate were not observed, and chlorite spotting, an alteration phenomenon characteristic of the Cobalt silver camp, was almost entirely absent. However, quartz ± calcite veins were observed occasionally in isolated parts of the upper, varied-textured zones of the Nipissing Diabase sill. In some instances, they carried minor but significant gold, silver, and copper values (Table 060.1). Two such occurrences were found west and south of Whitewater Lake. Both sites had been previously tested with pits but no records exist describing this

TABLE 060.1: VEIN ASSAYS FROM BANTING AND BEST TOWNSHIPS. ASSAYS DONE BY THE TEMISKAMING TESTING LABORATORY, COBALT.

Sample No.	Host Rock	Au (oz/ton)	Ag (oz/ton)	Cu (%)	Pb (%)	Zn (%)
86-LNO-068	Qtz vein in granite	0.049	na	na	na	na
86-LNO-074	Qtz (±Ca) vein in diabase	nil	tr	tr	na	na
86-LNO-105	Qtz vein in mafic volcanic	tr	na	na	na	na
86-EMD-003	Qtz vein in granite	0.002	na	na	na	na
86-MCS-018	Qtz vein in granite	tr	nil	nil	nil	0.01
86-MCS-024	Qtz vein in granite	tr	0.05	0.01	0.03	nil
86-MCS-029	Qtz vein in granite	nil	tr	0.01	0.01	nil
86-MCS-032	Qtz vein in granite	nil	tr	nil	0.01	nil
86-MCS-041	Qtz vein in granite	tr	nil	nil	0.01	nil
86-MCS-043	Qtz vein in granite	0.003	nil	nil	nil	nil
86-MCS-045	Qtz vein in granite	0.020	nil	0.01	nil	nil
86-MCS-047	Qtz vein in granite	tr	nil	0.01	nil	nil
86-MCS-048	Qtz vein in granite	nil	nil	nil	nil	nil
86-MCS-139	Qtz (±Ca) vein in diabase	tr	tr	0.48	na	na
86-MCS-143	Qtz vein in granite	0.004	na	na	na	na
86-MCS-152	Qtz (±Ca) vein in diabase	0.012	nil	na	na	na
86-MCS-156	Qtz (±Ca) vein in diabase	0.006	tr	na	na	na
86-MCS-162	Qtz vein in granite	0.009	na	na	na	na
86-MCS-163	Qtz vein in granite	0.010	na	na	na	na
86-MCS-165	Qtz vein in granite	0.002	na	na	na	na

activity. The veins average 20 cm in width and are composed of quartz, calcite, epidote, and small xenoliths of diabase. Pyrite, minor chalcopyrite, and malachite occur interstitially to the gangue minerals or as disseminated grains within the wall rock. In composite veins, drusy quartz extends inwards from vein margins to a central, carbonate-rich zone. In these veins, sulphide mineralization is located either at the quartz-calcite interface or associated solely with the quartz. Although there is little alteration of the diabase, sheared and slickensided surfaces suggest that movement and deformation accompanied vein development.

Quartz veins cutting granitic and volcanic rocks were systematically sampled, despite the absence of sulphide mineralization in virtually all cases. Samples returned gold values ranging from trace to 0.05 ounce per ton, suggesting that these vein structures should be further investigated.

The principal rock unit of economic interest is the hornblende gabbro, which will be assayed in future for platinum group element and base metal values in the magnetite- and sulphide-rich portions.

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061. Regional Sedimentology of the Lorrain Formation (Aphebian), Northern Cobalt Embayment

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Interest in the paleo-placer gold potential of the Lorrain Formation in the Cobalt Embayment results from the discovery of higher than background concentrations in the hematitic sandstone member in a small region of the northwestern portion of the embayment (initially reported by Colvine (1981)). Maximum values of 1200 parts per billion (ppb) were found in hematitic quartz pebble conglomerates (Colvine 1983).

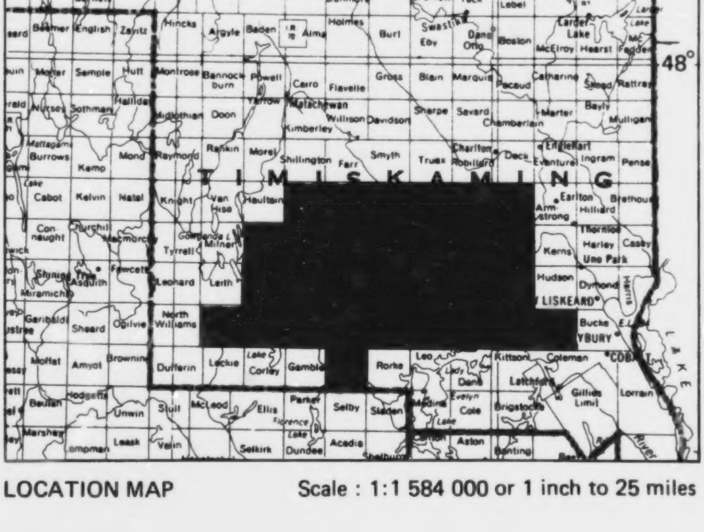
To facilitate a thorough evaluation of the paleo-placer gold potential of the Lorrain Formation in the Cobalt Embayment of central Ontario, a three-year project was initiated in May, 1986. The purpose of the project is to attempt to relate any anomalous gold occurrences to one, or an assemblage of, sedimentologic feature(s) displayed by the Lorrain Formation. This report summarizes the observations made during the 1986 field season.

As indicated on the location map, this first of three field seasons concentrated on the Lorrain Formation found in townships occupying the northern portion of the Cobalt Embayment. Emphasis was placed on the examination of the less readily accessible bush and lakeshore outcrop rather than restricting the investigation to highway exposures.

In addition to the evaluation of the depositional environment, a petrologic study is planned which will include an investigation of the trace element content of monocrystalline quartz framework grains and a heavy mineral study in an attempt to improve upon the existing, entirely lithological stratigraphic control within the Lorrain Formation.

PREVIOUS INVESTIGATIONS

The Lorrain Formation has been mapped by a number of previous investigators, principal amongst whom were Collins (1917) and Card *et al.* (1973). Previous sedimentologic studies are few. Hadley (1968) conducted his doctoral research on the Lorrain Formation in three areas of Ontario: Bruce Mines, Whitefish Falls, and Cobalt. He interpreted the depositional environment in this region as shallow marine to beach. Contrasting with this is the interpretation suggested by Long and Colvine (1985) for the formation in part of the northwestern Cobalt Embayment. They suggested that the lower and middle members of the formation and the basal part of the upper member represent deposition by a sandy braided fluvial system, while the upper part of the upper member might represent a tidally influenced beach facies. The only extensive prior petrologic study of the Lorrain Formation was conducted by Hadley (1968) as part of his doctoral research. The current study of the Lorrain Formation is distinct from earlier work in that it constitutes the first regional sedimentologic and petrologic study of the formation throughout the Cobalt Embayment.


80°
48°
KIRKLAND LAKE
T I M I S K A M I N G
LISKEARD
COBALT
LAKE
River
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Bernhardt
Morrisette
Katrine
Dasien
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Chaput Hughes
Grenfell
Teck
Lebel
Gauthier
Mc Vittie
Mc Garry
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Eby
Otto
Boston
Larder Lake
McElroy
Hearst
McFadden
Sample
Hutt
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Skead
Rattray
Nursey
Sothman
Halliday
Midlothian
Doon
Yarrow
Matachewan
Willison
Davidson
Sharpe
Savard
Chamberlain
Marter
Bayly
Mulligan
Kimberley
Burrows
Kemp
Mond
Raymond
Rankin
Morel
Shillington
Farr
Smyth
Truax
Robillard
Charlton
Dack
Englehart
Evanturel
Ingram
Pense
Cabot
Kelvin
Natal
Knight
Van Hise
Haultain
Earlton
Hilliard
Brethour
Armstrong
Connaught
Churchill
Tyrrell
Milner
Thornloe
Harley
Casey
Kerns
Uno Park
Asquith
Fawcett
Leonard
Leith
Hudson
Dymond
Miramichi
Garibaldi
Sheard
Ogilvie
North Williams
Bucke
Moffat
Amyot
Browning
Dufferin
Leckie
Corley
Gamble
Rorke
Kittson
Coleman
Latchford
Gillies Limit
Lorrain
Beulah
Hodgetts
Unwin
Stull
McLeod
Ellis
Parker
Selby
Sladen
Cole
Evelyn
Brigstocke
Marshay
Leask
Vogt
Selkirk
Dundee
Acadia
Aston
Banting
Shelburn

LOCATION MAP   Scale : 1:1 584 000 or 1 inch to 25 miles

STRATIGRAPHY AND SEDIMENTOLOGY

STRATIGRAPHY

The Lorrain Formation is stratigraphically the second lowest formation in the Cobalt Group, which is the uppermost group of the Huronian Supergroup. It varies from approximately 1500 to 2400 m in thickness (Hadley 1968) and is conformably and gradationally underlain and overlain by the Gowganda Formation and Gordon Lake Formation, respectively. Collins (1917) suggested that the Lorrain Formation in the western Cobalt Embayment could be partitioned into a lower feldspathic arenite, a middle less feldspathic arenite, and an upper white quartz arenite. Hadley's (1968) observations led him to suggest that the three-fold compositional subdivision proposed by Collins could be extended throughout the Cobalt Embayment (Long and Colvine 1984). A more complicated seven member subdivision of the Lorrain Formation was suggested by Card *et al.* (1973) as a consequence of their mapping in the Maple Mountain area of the central Cobalt Embayment. The author's observations in the northern Cobalt Embayment (*see* location map) indicate that the simpler subdivision of the formation suggested by Collins is most appropriate. As stated by Long and Colvine (1984), the additional members proposed by Card *et al.* (1973) are transitional in the field and difficult to objectively discriminate.

SEDIMENTOLOGY

While occasional fault scarp faces in the bush or lakeshore outcrops provide up to 10 to 15 m of vertical exposure, most outcrops examined were glacially rounded, highly lichen-covered, and usually presented vertical faces less than a metre in height. While this type of exposure precludes a section measuring approach, an assessment of the vertical sequence of sedimentary features can still be obtained by careful examination of the numerous small, near vertical faces found throughout a given outcrop.

Larger Scale Sedimentary Features

When present, larger scale sedimentary features can provide critical information with respect to the interpretation of the environment of deposition. Examples of such features are large scours created by channelized flows in either a marine or fluvial environment, and first order erosion surfaces formed by composite bedform migration in an aeolian desert environment. The recognition of such features requires large, well exposed, clean outcrops. Only rarely were bush or lakeshore outcrops of the Lorrain Formation of this quality. However, several outcrops along Highway 560 between the Towns of Elk Lake and Gowganda do permit the recognition of larger scale features. Two types were recognized in outcrops of the Lorrain Formation:

1. concave-upward surfaces of erosion with an amplitude of several metres and a width of at least several metres (both sides of the erosion surface were never seen due to outcrop quality). Such features were only noted a few times within the area investigated and in no instance was the scour surface lined with a lag deposit. These features represent erosion by channelized flows
2. irregular erosion surfaces showing no marked concavity, but of a greater lateral extent than the concave-upward erosion surfaces. They are very common throughout the area investigated and are at least several metres in lateral extent, commonly extending throughout the lateral dimension of the outcrop. The amplitude of the irregularities along this surface is usually quite small. They constitute surfaces of amalgamation between the overlying and underlying sandstone. Occasionally, a quartz granule to pebble lag occurs along these surfaces

Smaller Scale Sedimentary Features

While occasional outcrops show no apparent stratification, smaller scale primary sedimentary structures are visible in the majority of the outcrops examined. Arranged in order of decreasing frequency of occurrence, these structures are as follows:

1. normally graded units, usually from 2 to 15 cm thick, with a coarse sand or granule size lag at the base and an apparent lateral extent of several tens of centimetres
2. scour and fill pockets containing granule and pebble size detritus
3. usually large scale, planar tabular, and trough cross stratification; crossbedding is more common than crosslamination
4. symmetrical and asymmetrical ripple marks
5. parallel lamination
6. soft sediment deformation structures such as convolute lamination and flame structures

There is no consistent vertical sequence of sedimentary structures which characterizes Lorrain Formation outcrop. Generally, sedimentary structures are difficult to detect, especially in the white quartz arenite of the upper member. In many outcrops they are only visible due to an accentuation by heavy mineral lag.

Paleocurrent Analysis

Figure 061.1 presents a preliminary analysis of the paleocurrent data collected from the northern Cobalt Embayment. The arrows represent the dominant flow direction at each location from which directional data was obtained. In some cases they constitute vector means of a number of readings, in other instances they represent only one reading. The data at this time are uncorrected for structural tilt. In general, the data indicate a southerly paleoflow with the majority of flow vectors oriented toward the southwest or southeast.

Stratigraphic Arrangement

A consistent internal stratigraphic arrangement was displayed throughout the area investigated regardless of which member of the formation was being examined. The outcrops studied indicate an amalgamated series of sandstone bodies varying from several tens of centimetres to several metres in thick-

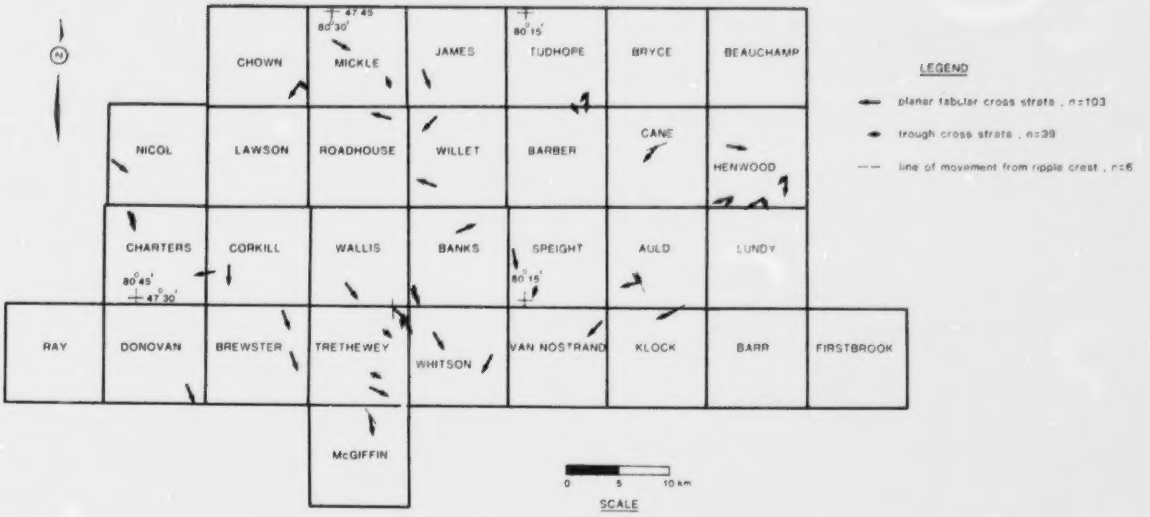


Figure 061.1. *Preliminary analysis of paleocurrent data collected from the Lorrain Formation in the northern Cobalt Embayment. The data is uncorrected for structural tilt at this time.*

ness. These bodies commonly display a cap of slightly finer grained and slightly more micaceous sandstone, usually varying between 2 and 15 cm in thickness and commonly pinching out laterally over a distance of several metres. This stratigraphic arrangement is shown in Photos 061.1 and 061.2. The capping units are commonly, but not always, recessive weathering and often display a slight greenish colouration. An example of a capping unit is illustrated in Photo 061.3. While their basal contact is always gradational, the upper contact with the overlying coarser grained sandstone body is variable. Most commonly it is erosional, but occasionally it, too, is locally gradational. Both symmetrical and asymmetrical waveforms occasionally occur along this contact. An example of symmetrical waveforms is illustrated in Photo 061.2. The upper contact is the irregular erosion surface mentioned previously in the discussion of larger scale sedimentary features. As a consequence of erosion during the deposition of the overlying sandstone these finer grained more micaceous caps are frequently locally scoured out. This accounts for their usually limited lateral extent and lensoid shape. Where they have been totally eroded only the surface of erosion (amalgamation) remains.

The sandstone bodies between the capping units most commonly display scour and fill pockets with granule and pebble size detritus and a stacked series of normally graded units indicative of repetitive waning flows. The normally graded units vary from approximately 2 to 15 cm in individual thickness and have a limited lateral extent of tens of centimetres. Large scale planar tabular and trough crossbedding, and the other smaller scale sedimentary structures previously mentioned, occur less frequently in the intervening sandstones.

DISCUSSION

While no final interpretation of the depositional environment of the Lorrain Formation can be made at this time, it is appropriate to comment on a marine versus a fluvial interpretation. None of the sedimentary features displayed by the Lorrain Formation in the northern Cobalt Embayment precludes a marine interpretation. Large scours, small scour and fill pockets, planar tabular and trough cross stratification, granule and pebble lag horizons and normally graded units can certainly form in a shelf setting. Shelves can also display some degree of uniformity in their sediment transport directions. Obviously, all of these sedimentary features could also be anticipated in a fluvial setting.

Similarly, a process to account for the occurrence of the often recessive weathering, more micaceous capping units can be conceived for either a fluvial or a marine environment. However, the occurrence of symmetrical waveforms along the upper contact of the micaceous capping units at a number of localities representing all three members of the Lorrain Formation indicates oscillatory currents which are difficult to attribute to fluvial processes. The common occurrence of a stacked series of normally graded units is also considered to mitigate against a fluvial interpretation. Certainly, the temporal and spatial variation in flow vectors within a river channel could easily result in the formation of normally graded units. However, in the author's opinion, the occurrence of a stacked series of such units indicating temporally close spaced, waning flows is more easily attributed to repetitive sediment disturbance by waves feeling bottom than to a variation in river channel flow structure. The key to the determination of the sedimentary environment in which the Lorrain Formation was deposited is considered to be the interpretation of the often recessive weathering capping units; in particular, the reason for their partial to complete removal.

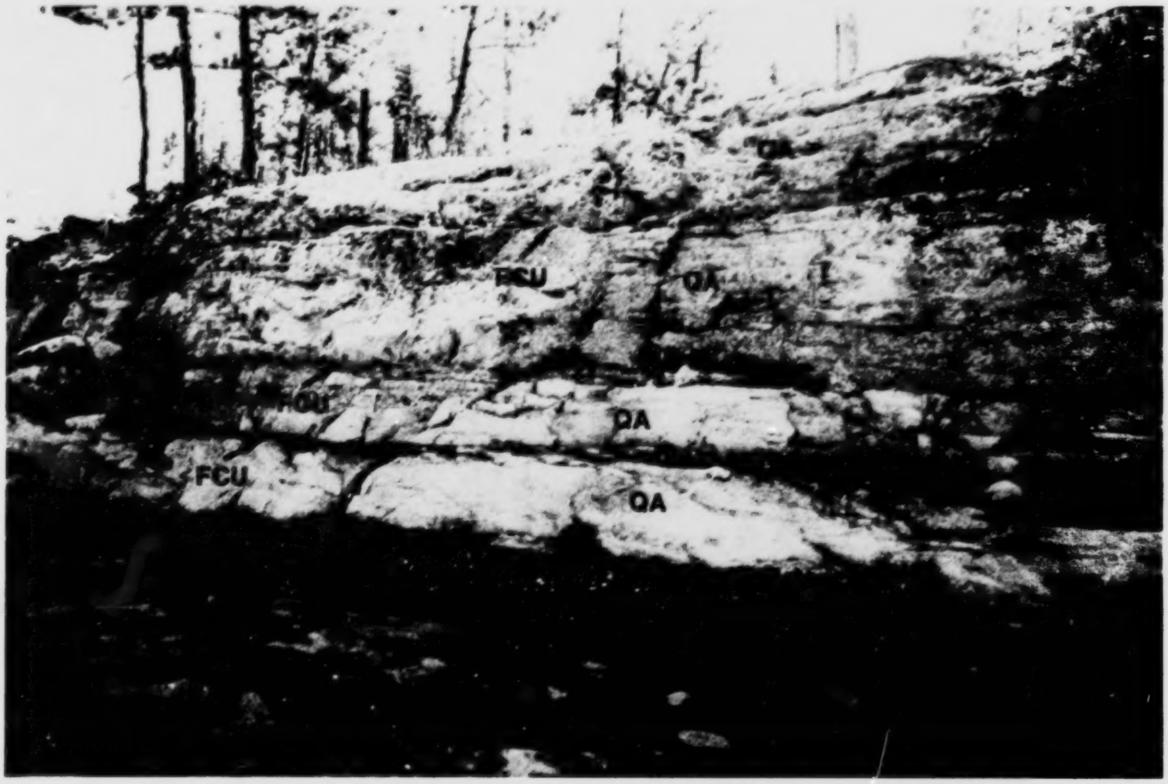


Photo 061.1. *The stratigraphic arrangement displayed in the white quartz arenite member (upper member of Collins (1917)) of the Lorrain Formation on southernmost Makobe Lake in northern McGiffin Township. Four tabular bodies of coarser grained quartz arenite (QA) are separated by three recessive weathering, finer grained, more micaceous capping units (FCU), several centimetres thick, that cap with gradational contact the three lowest tabular sandstone bodies. The trees in the background at the top of the photo provide the scale.*

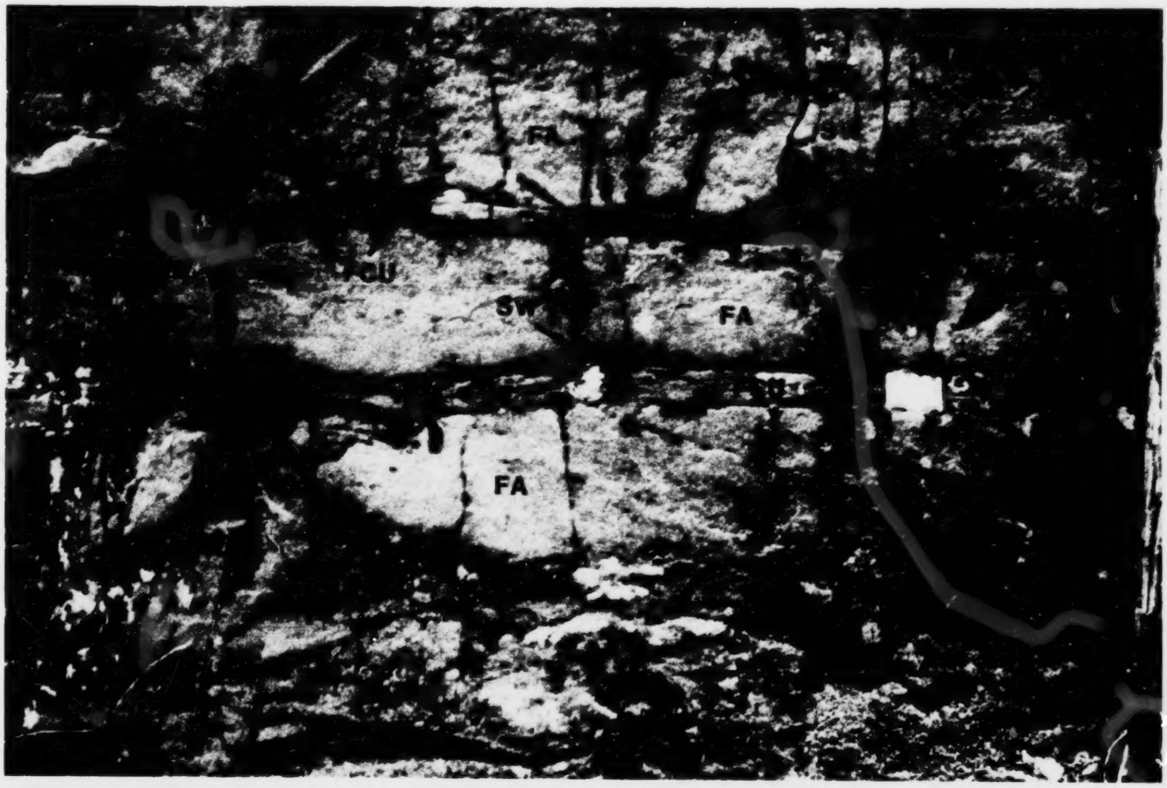


Photo 061.2. *The stratigraphic arrangement displayed in the feldspathic arenite member (lower member of Collins (1917)) of the Lorrain Formation in southwestern Auld Township. Three coarser grained feldspathic arenite intervals (FA) are separated by two recessive weathering, finer grained, more micaceous sandstone capping units (FCU), several centimetres thick, that lie gradationally on the underlying sandstone body. Both recessive weathering capping units display a symmetrical waveform (SW) along their upper contact with the overlying sandstone body. Note also the cross stratification accentuated by moss growth along a foreset in the lower sandstone body. The scale is 8.6 cm in length.*

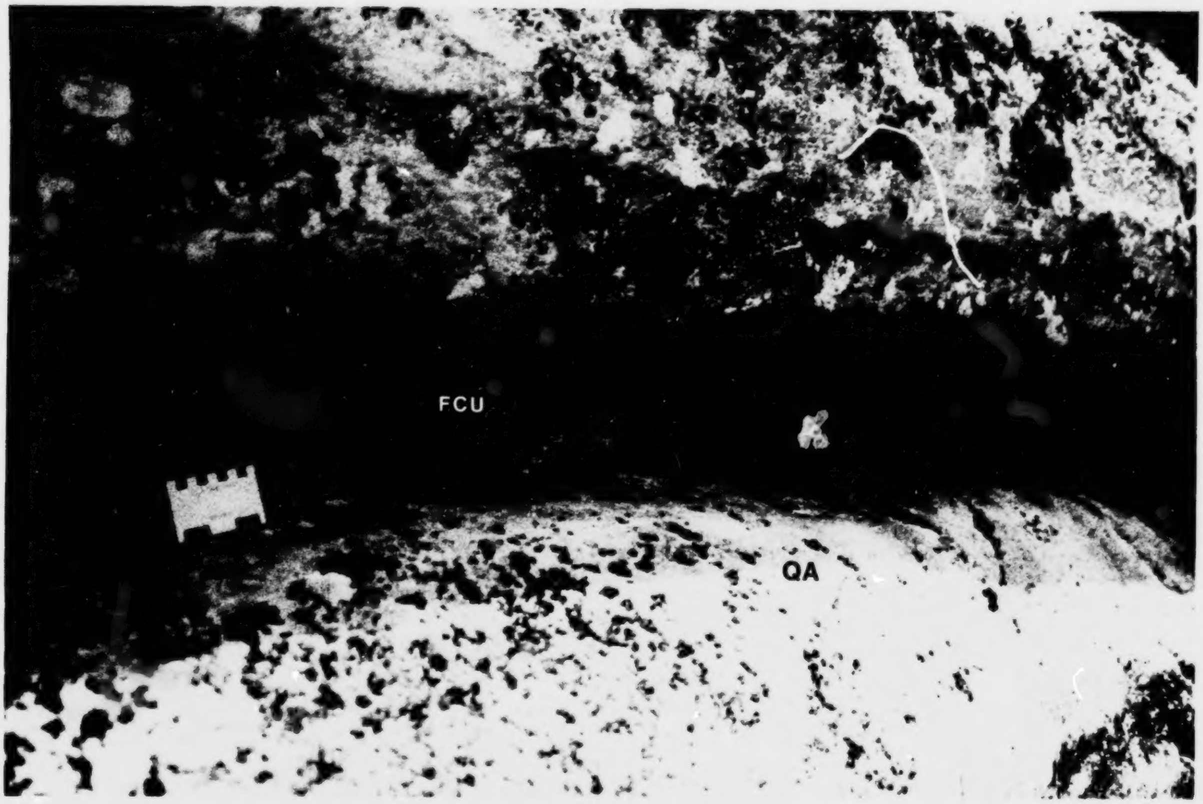


Photo 061.3. *A recessive weathering, finer grained, more micaceous sandstone capping unit (FCU) gradationally overlying the coarser grained underlying quartz arenite body (QA). The upper contact with the overlying coarser grained quartz arenite body (QA) is erosional. The outcrop is of the white quartz arenite member (upper member of Collins (1917)) of the Lorrain Formation on southern Makobe Lake in southern Trethewey Township. The scale is 8.6 cm in length.*

Samples of the Lorrain Formation from the northern Cobalt Embayment are in the process of being analyzed by the Ontario Geological Survey, Geoscience Laboratories, Toronto. No statements regarding their gold content or its areal distribution can be made at this time.

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062. Igneous Apatite for Soil Additives: Development of an Agricultural Technology Using Northern Ontario Materials

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INTRODUCTION

Superphosphate fertilizers are expensive, even for Canadian farmers. In Third World countries they are far beyond the means of ordinary small producers, or even of a whole country, if foreign exchange currency must be found to pay for their purchase. Yet, recently a study for Oxfam (Park and Jackson 1985) showed that the productivity of the small farmer in underdeveloped countries is vital to a stable, long-term food supply. In Zimbabwe, for example, where deliberate steps were taken to encourage them, subsistence farmers became producers of an agricultural surplus, which now amounts to 60 percent of all agriculture production.

Phosphorus is a key growth element. The Food and Agricultural Organization of the United Nations estimates that, in order to make long-term differences in agricultural patterns, Africa needs five times the amount of fertilizer that it now uses. Because of cost and currency difficulties, however, many farmers will continue to exhaust their soils, with increasingly lower yields.

Conventionally, phosphorus is added to soils in processed form because natural phosphate minerals are considered too insoluble to be effective. However, the availability of local supplies and a pressing need for phosphate has led to several attempts to use unprocessed materials as a top dressing. In Africa, where sedimentary phosphate is scarce, application of igneous phosphate, rendered friable by tropical weathering of carbonatite rocks, has been attempted (Landa 1982; Landa *et al.* 1983). However, until phosphate of this origin was composted (Landa and Karasira 1984) or mixed with manure (Bahaminyakamwe 1985), it was indeed too insoluble to be efficient as fertilizer. In the presence of abundant organic matter and in acid soils, however, there were slight indications of increased solubility of the phosphate mineral.

The connection between these studies and northern Ontario is provided by the carbonatite intrusions, which form part of the bedrock and which are capped by an ancient horizon of tropical weathering in northern Ontario. Ironically, the phosphate-rich gravels over the carbonatites are sealed by a thick layer of glacial clays, which results in soils that are highly deficient in phosphate. By 1980, field trials at Agriculture Canada's Experimental Farm at Kapuskasing, less than 25 km from a buried source of phosphate gravel at the Cargill Deposit, had shown that the application of phosphate alone made dramatic improvements in the growth and density of grassland on Great Clay Belt soils. Thus, the Kapuskasing area began to show itself as an ideal location for tests on the solubility of mineral phosphate for its own needs. Moreover, the similarity of setting between Cretaceous weathering on the Cargill body and modern African soil profiles suggested that this was a natural laboratory where a technology applicable to Third World countries might be tested.

TESTWORK ON APATITE FROM THE CARGILL DEPOSIT

Interest in making apatite of the Cargill carbonatite body near Kapuskasing more soluble for agriculture has spread. Both the Kapuskasing Experimental Farm and the University of Guelph have work presently underway. Recent data from Agriculture Canada (Mathur *et al.* 1986) have shown that 37 to 40 percent of mineral phosphate was made soluble and "plant-available" by composting the raw mineral phosphate from Cargill with various organic wastes under controlled conditions (Table 062.1). These are better results in terms of plant nutrition than can be obtained using sedimentary phosphates, and even better than using superphosphates, particularly in soils like those of northern Ontario which contain free calcium carbonate or high amounts of iron oxides and hydroxides.

Mathur *et al.* 1986 report:

> "With the aim of determining the feasibility of partial solubilization of the igneous phosphate rock (PR), we used eight combinations of 2, 3, or 4 of the following materials: Farm-yard manure (FYM), including manure and litter; liquid cow manure (LM) with 8% solids; straw (S); wood waste (WW); blood (Bl); and peat. Some composts were prepared aerobically (Ae), others first anaerobically (An) and then aerobically. Control composts did not contain PR, and had an average total P content of 0.29% (0.14 to 0.38%) while those with PR had 2.44% total P (1.66 to 3.51%). The inclusion of perforated horizontal pipes in trapezoidal heaps for aerobic composting, and enveloping of water-logged composts in plastic sheets on the ground for anaerobic composting helped make the processes cheap and facile for both manual and mechanical systems.
>
> Upon completion in 2 to 4 months, the extent of the total P added by the igneous PR that was solubilized into 'plant available' forms in the various composts was: 37.1% in LM + WW + peat (Ae); 40.2% in FYM = peat (Ae); 47.3% in FYM + S (An); 47.4% in FYM + peat (An); 52.8% in FYM + WW + Bl + peat (Ae); 62.8% in LM + peat (An); 63.9% in FYM + peat (Ae); and 74.4% in LM + peat (Ae). The average solubilization of the PR by the composting was 53.2%. In all the composts some of the PR was solubilized, thus suggesting that, like sedimentary PR, igneous PR can also be substantially solubilized by composting with various wastes.
>
> It is known that the aliphatic organic acids (e.g. citric, lactic, succinic), phenols, phenyl carboxylic

TABLE 062.1: PERCENTAGE CARGILL MINERAL APATITE MADE SOLUBLE BY COMPOSTING WITH VARIOUS MIXTURES (AFTER MATHUR ET AL. 1986).
FYM = Farm Yard Manure, PR = Phosphate rock, LM = Liquid Manure, WW = Wood Waste, B = Blood, P = Phosphate, RP = Rock Phosphate.

	Total P %	Soluble P %	Soluble P % of total	RP Soluble %
AEROBIC COMPOSTS				
3. FYM + Peat	0.25	0.18	70.7	
4. FYM + Peat + PR (Cargill apatite)	2.39	1.55	64.6	63.9
5. FYM + Peat (Mixed)	0.33	0.24	73.4	
6. FYM + Peat (Mixed) + PR	3.51	1.52	43.3	40.2
11. LM + Peat	0.35	0.32	91.6	
12. LM + Peat + PR	3.14	2.40	76.3	74.4
13. LM + Peat + WW	0.32	0.30	93.3	
14. LM + Peat + WW + PR	2.61	1.15	43.9	37.1
15. LM + Peat + WW + B	0.14	0.12	84.2	
16. LM + Peat + WW + B + PR	1.58	0.88	55.5	52.8
Average % RP Solubilization :				53.7
ANAEROBIC COMPOSTS				
1. FYM + Peat	0.22	0.20	91.4	
2. FYM + Peat	2.47	1.26	51.3	47.4
7. FYM + Straw	0.37	0.30	81.2	
8. FYM + Straw + PR	2.14	1.14	53.1	47.3
9. LM + Peat	0.38	0.32	85.8	
10. LM + Peat + PR	1.66	1.13	68.1	62.8
Average % RP Solubilization :				52.5

acids, amino acids, and complex humic and fulvic acids, which all chelate Ca and other metals; mineral acid ions (NO_3, SO_4, CO_3); and heat, all naturally produced during decomposition in the immediate vicinity of the PR granules in phospho-composts, dissolve the PR mainly as by partial acidulation treatments. It has been demonstrated that the organic and inorganic P in the above type phospho-composts is more available to crops than the P in 'soft' sedimentary PR, or even the superphosphate-P, particularly so in soils which are rich in 'P-fixing' Ca or in Fe oxides and hydroxides."

At the University of Guelph, Chesworth and his colleagues (Chesworth *et al.* in press) have tackled the problem of insolubility of apatite differently. In some soils, free calcium carbonate or hydroxide of iron and alumina cause reprecipitation of new complex phosphate minerals. This can be overcome by using a cation exchanger, which takes up Ca^{+2} and tips the soil equilibrium so that apatite continuously breaks down, giving a long term supply of phosphate-bearing anions. Zeolites and vermiculite are two natural minerals with cation exchange properties.

In plant trials, mixtures of Cargill apatite with a California zeolite (clinoptilolite) in quartz sand gave a potting medium in which corn showed good growth (Table 062.2). In mixtures with 1600±50 gm sand + 200 gm zeolite + 200 gm apatite, the growth (in dry weight) was six times greater than for a mixture of only quartz sand + apatite. Vermiculite, in preliminary trials (W. Chesworth, Land Resource Institute, University of Guelph, personal communication, 1986) also enhances solubility, but to a lesser degree. Future experiments will test vermiculte from the Cargill Deposit with the Cargill phosphate rock.

APATITE MIXTURES AS SOIL ADDITIVES

In the composting trials, one of the successful mixtures used liquid hog manure as an acid medium to dissolve the apatite, and peat to stabilize phosphate. Work in the USSR (Bulganina *et al.* 1983) had already shown that peat fixes ammonia in liquid wastes and that the addition of phosphate keeps the ammonia in a plant-available form. Local trials near Kapuskasing have shown that peat added to the liquid wastes in hog lagoons makes a moist, deodorized product which can be handled with a backhoe. The mixture becomes a useful soil additive, while at the same time eliminating the nuisance qualities of the liquid. It now appears that mixtures of composted apatite + peat + vermiculite + liquid manure may have potential as soil additives which are enriched in phosphate and nitrogen.

PRELIMINARY MINERALOGICAL TESTING

The dissolution of apatite during composting is obviously influenced by the composition and character of the mineral itself. It is already known that sedimentary phosphates are commonly more soluble than igneous apatite and that this reflects the crystal

TABLE 062.2: INCREASED SOLUBILITY OF MINERAL APATITE IN THE PRESENCE OF ZEOLITES SHOWN IN REPLICATED POT TRIALS. CORN YIELDS IN TERMS OF DRY WEIGHT AFTER 4 WEEKS GROWTH (FROM MATHUR ET AL. 1986).

	Dry Weight (gm)		Bulk pH
Quartz + Clinoptilolite[1]	0.96		6.8
(Ash Meadows, California)	0.90	0.84 ±0.19	6.7
	0.65		7.0
Quartz + Clinoptilolite[2]	1.15		5.8
(Kennecott, California)	1.09	1.06 ±0.09	6.0
	0.95		6.8
Quartz + Apatite[3] (Cargill)	0.37		5.9
	0.46	0.38 ±0.089	6.3
	0.32		6.3
Quartz + Clinoptilolite[1] + Apatite	2.42		7.1
	2.64	2.43 ±0.19	7.1
	2.24		7.0
Quartz + Clinoptilolite[2] + Apatite	2.26		6.9
	2.52	2.41 ±0.11	6.6
	2.46		6.7

[1] Clinoptilolite, Ash Meadows, California.
[2] Clinoptilolite, Kennecott, California.
[3] Apatite from Cargill, Ontario

chemistry. Mathur *et al.* (1986), in a preliminary investigation of untreated phosphate sands collected from stockpiles at the Cargill Deposit, reported:

> "The hard igneous phosphate rock (PR) from the Cargill deposit in northern Ontario, Canada, used in this study, is mostly macrocrystalline apatite with some crandallite, calcite and dolomite. The PR has 16% total P, 0.8% P soluble in citric acid, and 0.03% P soluble in ammonium citrate. About 44% of the beneficiated ore is <1 mm in size and 88% is >0.25 mm".

The geological setting of the weathering at the Cargill Deposit is discussed by Ford (this volume). Grab samples were collected by the author from the Cargill site in 1985 while stockpiling of the apatite sand underlying glacial overburden was being done by Sherritt Gordon Mines Limited, which hold the option on the property. The company went on to screen and beneficiate, by flotation, a stockpile of phosphate-rich grey ore from the sand.

The ore varies in colour from grey, the most phosphate-rich, to dull red and black. Colour is influenced by the content of iron minerals and the amount of carbonaceous debris. Microscopic examination of the black ore showed grains of quartz, Ca-phosphate, and limonite in a fine-grained matrix of Ca-Al-Fe-phosphate. The granular material ranges up to 200 microns in size. The limonite contains relicts of pyrite. More evidently peaty samples were a cellular, mainly organic, carbonaceous material intergrown with gypsum.

The red residual ore showed coarse (up to 500 micron) grains of quartz and Ca-phosphate in a matrix consisting of an intimate intergrowth of Ca-phosphate, kaolin, and titanium-bearing limonite with minor quantities of ilmenite.

Fine grey residual ore contains granules of quartz and Ca-phosphate in a fine-grained matrix of kaolin, phosphate, and Ti-Mn-bearing limonite with minor quantities of ilmenite and hematite. A coarser grey ore contained rounded grains of Ca-phosphate, up to 1 mm in size, in a porous, partly banded matrix of Ca-phosphate in which inclusions of Mn-bearing ilmenite occur at the 0.5 to 1 volume percent level.

Subsequently two samples of ore concentrate were examined—a brown concentrate and a pale grey concentrate. Both samples consist mainly of apatite. Minor mineral components are ilmenite, hematite, and intergrowths thereof. The volume proportion of these opaque minerals in the two samples was was established by microscopic grain count; as 8.4 and 2.6 volume percent. There are small quantities (less than 1 volume percent) of silicates, mostly amphiboles, and calcium carbonates. The apatite was found to be virtually free of chlorine (0.1 percent).

X-ray diffraction gave the pattern of fluorapatite, $Ca_5F(PO_4)_3$. The presence of fluorine was not confirmed, since the analytical method used could not record this element. Only calcium and phosphorus were detected.

Most of the apatite grains are rounded compact particles, up to 400 microns in size. There are other apatites which are porous, often with porosities arranged in bands. Many of these particles are angular, most likely fractured during milling. They probably represent apatites formed by a secondary process while the rounded apatites are primary.

The two types of apatite appear to have slightly different compositions. The following determinations were made of the CaO/P_2O_5 weight ratios:

	CaO	P_2O_5
Compact	58.4	41.6
	58.3	41.7
Porous	58.8	41.2
	60.4	39.6
	61.3	38.7

The porous variety has a higher CaO/P_2O_5 ratio and this result should be confirmed by fully quantitative analysis of well characterized grains.

POTENTIAL ECONOMIC DEVELOPMENT

Several economic opportunities are rising from attempts to use northern phosphate as an agricultural supplement:

1. Composted apatite can be used to correct phosphate lack in the Great Clay Belt soils.
2. Apatite mixtures with peat, vermiculite, and nitrogenous wastes can become the basis for manufacture of special soil additives.
3. These mixtures can potentially be pressed or formed into growing containers or fertilizer cubes. Simple proprietary technology for this already exists, ready to be adapted to northern communities.
4. These trials may be the basis for a saleable technology of apatite composting, which is applicable to agriculture in the developing nations.

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063. Pottery Clays in Northern Ontario

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INTRODUCTION

In October 1985, a conference in Kapuskasing brought together many of those interested in industrial minerals development in Ontario. One outcome of the meeting was to highlight the interest of Northern Ontario potters in clays that fire to stoneware temperature or higher. The tonnage of clay used annually in Ontario by potters is not great, but the profit on the articles made is sufficient to permit these workers to import their raw materials from outside Canada through a wholesaler and still make a satisfactory return. In these circumstances, supplies of quality clays close to existing centres of work might lower the cost of starter materials, and increase the profit margin. Thus preliminary work has begun, on a small scale, to search for and test clays which may be suitable.

THE ONTARIO ART POTTERY COMMUNITY

Production units in this category range from the individual hobbyist or production potter to automated, small manufacturers with 20 to 30 employees. The products are mostly decorative, but may also include functional goods such as tableware or lamp bases. In the greater Toronto area, a few of the manufacturers specialize in such pieces as electrical porcelain or bathroom accessories (Guillet and Joyce, in preparation).

In the northeastern part of the province, six population centres for potters can be identified. Ranked by decreasing order of numbers, these centres are: Kapuskasing-Hearst, North Bay, Timmins, Sudbury, Manitoulin, and Chapleau. Their output is mostly decorative ware, ranging from low temperature terra cotta to high-fired porcelain sculpture.

Preliminary market research of clay suppliers and users (Guillet and Joyce, in preparation) suggests that 2500 to 3000 tons of clays are used annually by potters in Ontario. Prices range from $600 to $720 a ton. Material may be supplied as 50 pound bags of dry, screened clay, or as a wet ready mix.

The value added on goods made of the high-temperature-fired kaolin or kaolinite ball clays is greater than on clays of lower firing temperature because the products have special properties of strength, lightness, and impermeability. A porcelain tea cup, for example, is a more valuable product than a flower pot. Thus the economics of working with materials that have superior qualities is better than if lower quality, cheaper materials are used.

In Ontario, more than 2000 tons of kaolinitic materials are imported annually, largely from the United States. Ontario clays of this quality are present but are not available in standard ready-prepared form. Most of the larger users of kaolin materials are centred in the Greater Toronto area. In northeastern Ontario, both kaolinitic clays and the lower firing stoneware clays are needed. In the last five years, potters and suppliers (Frank Tucker, Tucker's Pottery Supplies, Markham, Ontario, personal communication, 1985) have noticed a decline in the fired temperatures that can be achieved with supplies from traditional sources. They would welcome a steady supply of quality material from a Canadian source, provided the properties were good enough and constant enough, and the price was competitive. Furthermore, those in the art pottery trade suggest that, were the price and quality right, an annual market of 1500 to 2000 tons exists for exporting stoneware clays to the northeastern United States.

THE SEARCH IN ONTARIO

Given that Hearst-Kapuskasing is a centre for potters, the search so far has been concentrated from Cochrane westwards along Highway 11. The expected geological setting can be estimated from prior work. To date, the best quality materials recorded are Cretaceous in age. At that time, Northern Ontario was a land surface weathering under a humid, subtropical climate (Hopkins and Sweet 1976). Quartz-feldspar sands, worn from the older Shield rocks, were washed into depressions and valleys on that surface, and carried northwestwards by an extensive river system that drained towards the present Prairies (Try *et al.* 1984). During weathering, the feldspars were broken down to kaolin, which was either held within the river sands or redeposited as purer lenses in clay banks downstream. Where the Shield rocks were already strongly fractured, erosion was more rapid. These areas became topographic depressions where sand and kaolin collected. Hollows also formed where marbles or other rocks such as carbonatites, containing calcium-magnesium carbonates, were affected by karst development in a tropical environment.

This means that the search for promising materials must be concentrated at the old Cretaceous land surface. The better clays will normally be covered by glacial debris and will lie in protected locations, which are commonly fault-controlled valleys. In sequences of known Cretaceous rocks, such as those that crop out in the Mattagami and Missinaibi Rivers, the pale colour, lack of free calcium carbonate, and a consistency like fresh putty, have already drawn attention to the kaolinitic clays. However, in locations where quality materials are unexpected, these valuable clays may easily be overlooked or discarded. The search for them is made difficult as there is no method other than drilling to detect them beneath a glacial cover. Hence, many discoveries are accidental, in the search for other commodities.

FINDS IN ONTARIO

The well known exposures of Cretaceous clays have been thoroughly tested (Dyer and Montgomery 1929; Montgomery 1929; Mercier 1963; Bell and Zemgals 1974). Their quality is already established though their extent needs to be evaluated. Their principal disadvantage, however, lies with the land tenure. The larger well known deposits are held by private owners or large companies, who, aware of the potential value they control, would require profit margins far beyond the means of small enterprises. Thus it is necessary to search for new finds, particularly those that are easily accessible on existing roads or close to the surface.

KAOLIN FROM THE CARGILL DEPOSIT

The geology of the Cargill carbonatite intrusion (Figure 063.1) has been described by Sandvik and Erdosh (1977, 1984). The bedrock lies beneath 5 to 10 m of glacial lake clay which covers a strongly dissected Cretaceous land surface on which fault-controlled valleys up to 130 m deep are filled with sands, peaty debris, and lenses of kaolinitic clay. Drill core from the southwestern end of the body shows a thickness of 22 m of pure kaolinite at one point. Topographic highs on the old land surface, however, are bare of preglacial overburden.

The surface of the carbonatite has been partly stripped by Sherritt Gordon Mines Limited, which holds the option on the land. Their interest was to obtain a bulk sample of the loose residual apatite gravels which were formed from the carbonatite by Cretaceous weathering. Both the glacial clays and the preglacial overburden were removed as waste.

Samples collected by the Ontario Geological Survey (Vos 1981) confirmed the presence of kaolinite. X-ray diffraction studies gave values of up to 50 percent kaolinite in these greyish white clays. Tests commissioned for a seminar in October 1985 showed that the material has excellent handling and firing characteristics. The craftsperson (T. Pollard, artist, North Bay, personal communication, 1985) comments that the sample:

> "is impressive for its whiteness, less plastic than most, but the possibilities are limitless. This kaolin could be used for coloured casting and a decorating slip in glazes where a slight iron content can complement rather than hinder the finished product. Casting proved successful as did throwing and hand building. The shrinkage is really low for a kaolin, a pleasant surprise, and it is oven proof. This clay has to be cleaned before use, but is well worth the effort."

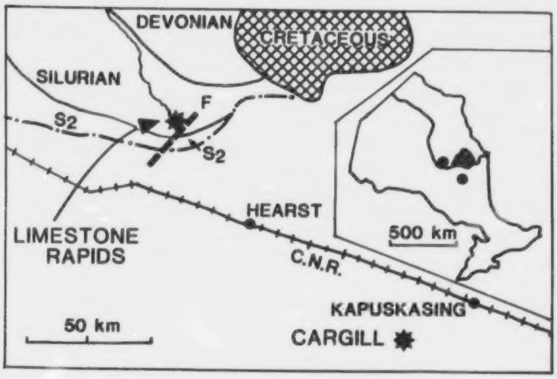

Figure 063.1. *Location of the Limestone Rapids section.*

In 1985, Sherritt Gordon Mines Limited stripped a larger area in order to recover and concentrate a stockpile of apatite sand. Grab samples of impure kaolinitic clays were collected while stripping was in progress. Later, in May 1986, material was hand-cobbed from the stockpiles of clay waste and from the vicinity of the primary crusher.

Mineralogical examination of the untreated white clays shows corroded grains of quartz in a groundmass of fine kaolinite less than 5 μm in size. The kaolinite itself has a low content of titanium and iron (0 to 0.74 percent TiO_2, 0.69 to 0.86 percent Fe_2O_3). Otherwise it is a very pure kaolinite with a well formed crystalline structure. Further testing (J. Agnew, production potter, North Bay, personal communication, 1986) has confirmed that this clay fires whiter than the ball clays obtained from the Kipling Dam section on the Mattagami River. Its firing temperature of at least Cone 10, and a linear shrinkage of only 3 to 4 percent, means that this is a material suited to products as exacting as refractory brick liners for furnaces. It would considerably enlarge the range of products that are possible for the pottery community in the north.

Practical disadvantages to this site are that the land claims are held by a company that has decided that, given the current outlook for potential phosphates on the world market, they will not proceed with development. Another disadvantage is that, although kaolinitic clays may be widespread across the 15 km^2 area of the carbonatite, they are probably thin and patchy. The subsurface valley where 22 m thicknesses of kaolinite are reported from drill core is overlain by a lake in today's topography.

This, however, is material of superior quality. Moreover, if it can be supplied "as dug", this may represent a valued property of the clay. One artisan (E. Lindgren, potter, Huntsville, personal communication, 1986) comments that:

> "The processing (i.e. flash drying) of the available clays is not appropriate to the desired characteristics of clay. The damage to the plastic properties cannot be rectified. For potters, the inherent plasticity of the clay, as dug, is most desirable and cannot be reachieved realistically after flash drying. There is a supplier near la Borne, France, who sells to potters and schools across Europe (at their great expense!) a clay body which has not been thus insulted, and indeed they (the potters in Europe) are lined up to get it."

HIGH-FIRING CLAY ON THE KABINAKAGAMI RIVER

In 1981, mapping by the Ontario Geological Survey identified a 12 m section of varicoloured Cretaceous clays that fill hollows in the Middle-Upper Silurian carbonates (Richard 1981a). Subsequent, unpublished work by the same author (Richard 1981b) described in detail the field occurrence and the mineralogy of this outlier, which is situated 58 km west-southwest of the main Cretaceous outcrop at Limestone Rapids on the Kabinakagami River (Figure 063.1). Reconnaissance work (Sanford *et al.* 1968) had already shown that a northeast-trending normal

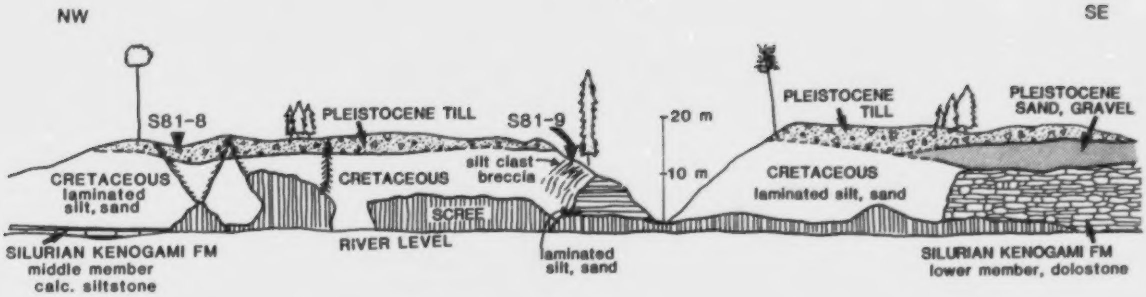
NW
SE
S81-8
PLEISTOCENE TILL
S81-9
silt clast breccia
CRETACEOUS laminated silt, sand
CRETACEOUS
SCREE
RIVER LEVEL
SILURIAN KENOGAMI FM middle member calc. siltstone
laminated silt, sand
20 m
10 m
PLEISTOCENE TILL
PLEISTOCENE SAND, GRAVEL
CRETACEOUS laminated silt, sand
SILURIAN KENOGAMI FM lower member, dolostone

Figure 063.2. *Cross section at Limestone Rapids on the Kabinakagami River, showing distribution of Paleozoic, Cretaceous and Pleistocene units and location of profiles in Figure 063.3. After Richard (1981b).*

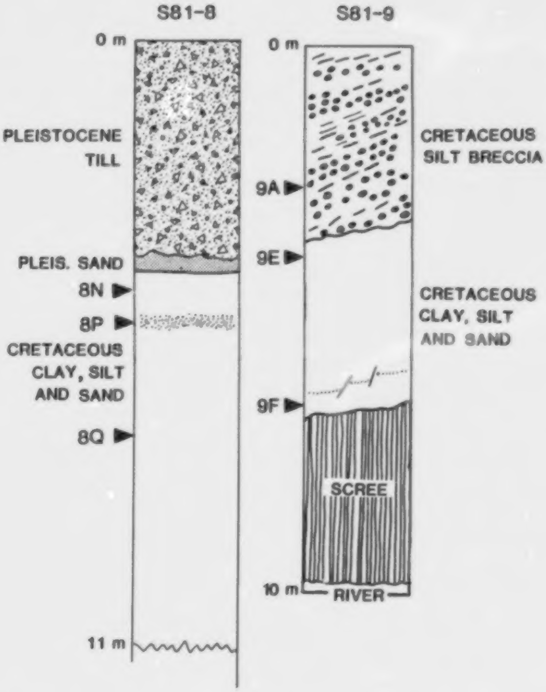
S81-8
S81-9
0 m
PLEISTOCENE TILL
PLEIS. SAND
8N
8P
CRETACEOUS CLAY, SILT AND SAND
8Q
11 m
0 m
CRETACEOUS SILT BRECCIA
9A
9E
CRETACEOUS CLAY, SILT AND SAND
9F
SCREE
10 m
RIVER

Figure 063.3. *Diagrammatic profiles of vertical sections at Limestone Rapids. See Figure 063.2 for locations.*

fault has raised the northwest block relative to the other side. Calcareous siltstones (middle member of the Silurian Kenogami Formation) are now at the same elevation as dolostones of the Lower Kenogami Formation. The river flows north and then northwest around a great bend at this point, exposing a panoramic section (Figure 063.2).

A broad hollow cut into both calcareous members appears to be a karstic feature. Its floor at the southern end of the section is Middle Kenogami Formation; at the northern end, the walls and floor are cut into Lower Kenogami Formation. At the centre, the hollow dips below river level. It is filled with 8 to 12 m of brightly coloured, unconsolidated clays and silts inferred to be of Cretaceous age. A measured section (S81-8, Table 063.1) at the southern end shows that the laminated infill dips gently southeast, towards the river. Near the middle of the face, another measured section (S81-9, Table 063.1) shows the laminated silts and sands cut and infilled by a silt clast breccia, held in a poorly bedded, strongly oxidized matrix. The breccia rests unconformably on a surface dipping gently northeast away from the river, and minor normal faulting of the lower sequence suggests that local settling northward has taken place.

MINERALOGY, FIRING BEHAVIOUR, AND CHEMISTRY

Mineralogical data from six samples, three from each measured section, are summarized in Table 063.1. Diagrammatic profiles of the sections are shown on Figure 063.3. Percentage data for the clay-sized fraction are shown in Table 063.2. These sediments are largely fine, clayey silts consisting of quartz-illite plus illite/smectite. They contain no carbonate. A pale clay (Sample 9E in S81-9) interbedded with sand in the northern section, below the silt-clast breccia, contains nearly 70 percent kaolinite, but this is local.

The potting and firing characteristics of these blue-green "clays" show considerable promise, and more test work is in progress. The clay has a fine particle size range and, in the unfired (green) state, shows low plasticity. This would make it more suitable for slip casting than handbuilding or working on a wheel. As slip casting is a fabrication technique which can be used to increase per capita production and thereby increase revenue, this characteristic may be very advantageous to the pottery community in Hearst-Kapuskasing.

Sample S81-9D (Table 063.3) fires to Cone 10 in the stoneware range. At this temperature, it is just beginning to vitrify. It shows development of interesting surface properties and, with some experimentation, may be the kind of material from which a characteristic local ware could be produced. When fired, it is a pleasing, red colour.

The chemistry of sample S81-9D is shown in Table 063.3, along with that of four other samples from the locality. It is compared with the composition of five Japanese clays, which have become the foundation for world famous local ware. The higher values of alumina and lower values of potash in the

TABLE 063.1: MINERALOGICAL DATA, FOR CRETACEOUS INFILL, LIMES ONE RAPIDS SECTION, IN RELATION TO MEASURED SECTIONS (After Richard 1981b).

Unit	Colour	Mean Grain Size (phi)	Sorting	Roundness	Sphericity	Lithology 170 10 mesh	Clay Minerals (ranked)	Carbonate Content
Section S81-8								
8N	dark steel-blue	6.4	poor	angular	low-moderate	85% Quartz 10% Muscovite 4% Heavies 1% Middle Range Fractions	Illite-A Quartz-B Smectite/illite-B Kaolinite, K-feldspar-minor	none <1%
8P	pale yellow 2.5 Y 7/4	3.6	poor	angular	low	90% Quartz 5% K-feldspar 5% Middle Range Fractions	Illite-A Quartz-B K-feldspar-D Kaolinite, Smectite/illite-C	none <1%
8Q	dark steel-blue	6.8	poor	angular	low	90% Quartz 6% Muscovite 2% Heavies 20% Middle Range Fractions	Illite-A Quartz-B Smectite/illite-C Kaolinite, K-feldspar-minor	none <1%
Section S81-9								
9A	red (2.5 YR 5/6), yellowish to olive tan and blue	7.5	poor	subangular	low	65% quartz 20% K-feldspar 10% Muscovite 3% Middle Range Fractions 2% Heavies	Illite-A Quartz-C Smectite/illite-B Kaolinite, K-feldspar-minor	none <1%
				UNCONFORMABLE CONTACT				
9E	white to light grey (5 Y 7.5/1)	3.7	poor	subrounded to subangular	moderate	90% quartz 8% K-feldspar 1% Middle Range Fractions 2% Heavies	Kaolinite-A Illite-B Quartz-C K-feldspar, Smectite/illite-minor	none <1%
9F	steel-blue	7.6	poor	angular	low	85% Quartz 10% Muscovite 5% Middle Range Fractions	Quartz-B Illite-A K-feldspar-C Kaolinite, Smectite/illite-minor	none <1%

TABLE 063.2: X-RAY DIFFRACTION MINERALOGY OF CLAY-SIZED FRACTION IN PERCENT (From Richard 1981b).

Sample	Smectite/Illite	Illite	Kaolinite	Quartz	Plagioclase Feldspar
Section S81-8					
8N	24	46	3	24	3
8P	16	52	3	24	5
8Q	19	48	3	26	4
Section S81-9					
9A	30	38	7	24	3
9E	8	14	69	7	2
9F	7	30	--	39	24

Japanese materials will mean that they fire to higher temperatures, but in other respects the absolute values of elements and the relative balance of refractory to flux elements shows considerable promise.

These preliminary results indicate that the deposits at Limestone Rapids are potentially a source of high-firing clay that may make possible the production of a quality pottery line that has a characteristic local signature. The deposit already has some practical advantages. It lies one hour by road from Hearst, and is accessible by a gravel road which runs through Rogers Township to the western bank of the river. On the eastern bank, a timber road approaches the river but is washed out in several places so that only snowmobile access is now possible. Site mapping of the deposit is required to assess the volume present and what problems might be encountered in mining. Preliminary materials testing is underway on a small scale, but more rigorous tests will be needed if the material continues to look promising.

CONCLUSIONS AND RECOMMENDATIONS

It appears that once geographical constraints, market needs, and geological setting are closely defined, it will be possible to search for quality materials to improve the economics of art pottery production in Northern Ontario. Geological reasoning suggests that there may be more local accumulations of clays that fire to stoneware temperatures and above. Moreover, in Southern Ontario interglacial clays and some lake clays of Pleistocene age have shown valuable characteristics, although they are not as high-firing.

It is recommended that a carefully directed search for pottery clays be initiated. Given the area to be searched and the manpower this would require, it makes sense to involve prospectors and the general public.

This work will require identification, in simple terms, of promising target locations and a straightforward, easy-to-apply procedure for field identification of promising materials. These guidelines should then be widely circulated through the local press and government offices so that local awareness of the value and appearance of quality clays is raised. The greater the number of trained eyes that search, the better will be the chances of finding the right materials.

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TABLE 063.3: CHEMISTRY OF CRETACEOUS SILTS, LIMESTONE RAPIDS, COMPARED WITH JAPANESE POTTERY CLAYS. (*Sample has firing data, see text. Japanese data, J. Agnew, potter, North Bay, personal communication, 1986).

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	CO_2	S	H_2O^+	H_2O^-	L.O.I.	Total
LIMESTONE RAPIDS SECTION																	
Section Base																	
S81-8	72.3	13.0	3.09	0.15	1.34	0.13	0.00	6.10	0.76	0.10	0.03	0.16	0.01	2.16	0.58	3.0	100.2
S81-9C	77.6	11.5	0.67	0.15	1.28	0.10	0.00	7.36	0.32	0.09	0.01	0.19	0.01	1.20	0.23	1.3	99.4
S81-9D*	70.7	13.8	3.15	0.15	0.01	0.12	0.00	6.79	0.67	0.08	0.03	0.16	0.01	2.40	0.50	3.0	100.0
S81-9F	70.0	13.8	3.20	0.22	1.40	0.13	0.00	6.21	0.71	0.09	0.03	0.19	0.01	3.01	0.57	3.7	99.8
Section Base																	
S81-9	73.3	12.1	2.96	0.15	1.59	0.16	0.00	6.30	0.68	0.10	0.03	0.18	0.01	2.21	0.51	2.6	99.9
FAMOUS JAPANESE POTTERY CLAYS																	
Pazen Clay	69.6	16.9	3.08		0.60	0.17	0.00	2.68	0.58	0.04	0.02	0.32	0.01			6.9	100.6
Arita "Student" Clay	70.7	18.4	0.60		0.29	0.42	0.98	3.16	0.18	0.05	0.02	0.46	0.01			4.9	99.7
Arita Porcelain	67.7	20.6	0.99		0.34	0.40	0.45	2.36	0.44	0.02	0.02	not assayed				6.2	99.6
Raw Onta Clay	58.6	18.8	8.46		3.47	0.07	0.07	0.90	0.77	0.29	0.03	not assayed				9.6	101.0
Paddled Onta Clay	56.7	21.7	6.05		2.79	0.15	0.00	2.34	0.74	0.13	0.04	0.44	0.03			9.1	99.7

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064. Foamed Clay: Applications for Northern Ontario

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INTRODUCTION

Some clays and shales expand on heating, and then cool to give a glassy, porous material which can be used to make glazed, cellular pellets, ideal as insulating aggregate in concrete, or for use as a lightener in potting soils. In Ontario, commercial production of expanded aggregate from a clay shale continued until 1980 (Wilson 1979), when rising fuel costs and difficulties of dust control from the stack forced the Mississauga plant to close.

Primary markets for expanded aggregate in Ontario have traditionally been ready-mix concrete and concrete block. Broad trends in the Canadian construction industry (Guillet and Joyce 1986) show that, in the period 1979 to 1983, the use of concrete block declined. Thus, the overall tonnage of expanded aggregate used also fell, and there was no corresponding growth of use in other sectors. Guillet and Joyce (in press) conclude that for a successful industry, substantial replacement markets must be found to offset the losses in the block industry; that diversified uses must be sought; that entry into the road-paving aggregate market should be attempted, and that production methods which minimize energy costs must be used. A study of the United Kingdom aggregate industry (Fleming 1977) points out that expanded aggregates must offer more than lightness if they are to offset the cost of additional processing and compete effectively with the stronger concretes that can be made with denser aggregates that need only to be dug, washed, and graded.

As the success of expanded aggregate in Canada is tied to the construction industry, let us look at its fortunes in some other countries. In contrast to Canada, Scandinavian markets for expanded clay aggregate are flourishing. The material is highly valued both for its sound absorbency, and for its insulation of heat. Companies in Norway and Denmark have put much effort into product development and customer service, aimed at both the ready-mix concrete and the prefabricated construction sectors

Northern Ontario has many features of population, size, and transportation in common with Norway and Sweden. The Swedish market for housing has the same problems of small size and fragmentation as Canada's, but although housing starts fell over 50 percent between 1973 and 1983 (80 000 to 37 000), Swedish manufacturers increased their production for domestic markets by 14 percent, and in 1985 half of the production was customized for markets in other European countries (Bairstow and Associates 1985).

Canada also needs appropriate, affordable, well-insulated housing. Demographic forecasts by the Canada Mortgage and Housing Corporation, discussed in March 1985 in relation to manufactured housing (Bairston and Associates 1985), point to special market opportunities in housing. These include the needs of northern communities and of special age groups such as the elderly or baby boomers, who will double the population in the 35 to 54 age group by 2001. Thus it seems that manufactured housing may represent a market large enough for viability. Even when expanded clay aggregate has disappeared from the southern Ontario construction industry, there may be local opportunities in the north. The "extra" that these light aggregates offer, in the north, is cost savings: better insulated housing cuts fuel bills in areas where those bills are inescapable, and where, if incomes are low, a large proportion of income is used to keep warm. A better product may become affordable if it is locally made.

In addition to the housing industry, potting soils are a market into which clay aggregates may be sold. There is local interest in both Ontario and Quebec in finding a substitute for vermiculite, which is presently imported from the States. Furthermore, quality aggregate for road beds is commonly scarce in parts of the north. All in all, at a time when world fuel prices have fallen dramatically, there seems good reason to examine further the idea that Northern Ontario could support small plants for expanded clay aggregate.

SCANDINAVIAN EXAMPLES OF USE

In Norway and Denmark, pelletized and foamed Pleistocene marine clays are used for a wide variety of products in which a rigid, well-ventilated medium is important. These pellets are used as loose-fill insulation in dry conditions; as insulation-plus-capillary shielding in foundations; and as strong, frost-resistant roadbed material. When combined with various cements, they have become the basis for a whole segment of the prefabricated building industry in which blocks, chimney units, wall or floor panels, and insulated composite blocks are pre-formed for various residential and industrial building needs. In addition, the material can be blown or poured on site as a slurry (Technical leaflets 1985 from A/S Norsk Leca, Norway and Fibo A/S, Denmark).

The pellets are also a component for potting soils, produced by a subsidiary company, A/S Lett-Jord. Mixes of 50 percent blond peat moss and 50 percent pellets, with a density of 205 kg/m^3 are retailed. The pH is adjusted to 5.5-6.0 using 1.5 kg/m^3 each of ground dolomite and limestone flour. Chemical nutrients (nitrogen, phosphorus and potash 15-4-12) and micronutrients (trade brand name FTE 36) are added at a rate of 1 kg/m^3 and 0.025 kg/m^3, respectively.

Independent work, quoted by the company, shows that De Boots, at the University of Ghent in Belgium, obtained a superior growing medium by virtue of its good aeration. Medium and coarse Leca pellets, in the 4 to 10 mm and 10 to 16 mm diameter range, were lighter in weight than either peat moss, composted bark, or composted domestic waste. The theoretical pore space available in peat moss or bark was greater, but the percentage of the pore space useful to soil function was significantly less.

NORTHERN ONTARIO MATERIALS SUITABLE FOR EXPANDED AGGREGATE

Little test work has been done on northern clays and shales for their bloating characteristics. A single sample from Rydal Bank, 60 km east of Sault Ste. Marie (Wilson 1963), bloats between 1075 and 1100°C, expands 35 percent and gives pellets with a bulk density of 890 kg/m^3, and a crushing strength of 5.3 to 35.7 megapascals (MPa). For comparison, Pleistocene marine clays, used in Norway as starter materials (Rutherford 1986), fire at about 1100°C to pellets with a bulk density of 320 to 500 kg/m^3 and a crushing strength of 1.7 MPa. This compares with Ontario specifications for lightweight concrete block which weighs, on average 1700 kg/m^3, with a crushing strength of 15 MPa (Mark Patamia, Technical Adviser, Ontario Concrete Block Association, personal communication, 1986).

New results from Ellis Township, 90 km north of Sudbury, indicate a clay that vitrifies with foaming below Orton cone 6 (1190°C) and fires to a dark red.

These two appear to be the only test work available. However, by comparing the requirements known from the literature against the available analyses, it can be inferred that clays of suitable chemistry are widely distributed as pockets across the north and that they may show the right characteristics in firing.

The most important characteristic for successful bloating clays is, of course, that they foam when heated. This requires a chemical composition which contains enough flux materials to form a molten glass of the correct viscosity, and a mineral content that will release gaseous components within the melting range. The raw materials should have a wide vitrification temperature, otherwise temperature variations in the kiln, which cannot practically be controlled to closer than 50°C, become difficult to handle. Chemically, the composition requirements are fairly tolerant (Table 064.1). Both chemistry and bloating properties can be adjusted using additives, although this increases production costs.

Although many surface clays in Ontario are rich in calcium carbonate, which lowers their ceramic quality, a few (Brady and Dean 1966) which resemble clays in plasticity and grain size are in fact fine quartz-feldspar rock flours with a proportion of micaceous minerals. The Ellis Township material is one of these, and a number more (Table 064.1) exist in Ontario.

These materials have some of the right chemistry, although to date the most thoroughly examined samples (Brady and Dean 1966) seem to evolve too little gas to foam well. Moreover the firing range is short, though controllable in some cases. However, as at least two localities (Ellis Township, Rydal Bank) have expanding materials, and since there are general arguments in favour of searching for such resources, efforts should continue to pinpoint the geological setting of these lime-free clays; to test the firing behaviour of the materials and to test the density-versus-strength characteristics of the pellets.

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TABLE 064.1: WHOLE ROCK ANALYSES OF NORTHERN ONTARIO CLAYS (*=new data, others from Brady and Dean (1966)), compared with compositional range needed for expanded clay pellets. All values in weight percent, N.D. = not determined.

	SiO_2	FeO	Fe_2O_3	TiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	LOI	Total	Total C	Org. & El. C	S	H_2O^+	H_2O^-	CO_2	Quartz
Ideal Oxide Composition for Foamed Clays	50-80		3-10		10-25	0.30	0-5	0-5	1-10	4-8				As SO_3 0-1.5				
Arnprior	58.31	2.62	4.52	0.86	16.92	3.48	3.64	3.10	3.35	2.88	99.68	0.14	0.06	0.023	2.80	1.63	0.26	18.4
Bracebridge	63.16	2.44	3.70	0.78	16.09	2.80	2.62	3.21	3.44	2.25	100.49	0.17	0.07	0.022	2.31	0.69	0.34	31.2
Napanee	56.76	1.91	5.76	0.95	18.23	2.28	3.87	1.78	4.15	4.77	100.46	0.21	0.14	0.018	3.70	2.47	0.21	16.6
Manotick	59.92	1.77	4.06	0.76	15.02	4.94	3.41	2.60	3.15	4.70	100.33	0.75	0.10	0.019	2.08	1.42	2.40	32.9
North Bay	63.72	1.16	4.52	0.67	16.08	1.58	2.28	2.40	3.30	4.60	100.31	0.60	0.55	0.019	3.30	1.38	0.17	36.1
Sudbury	65.12	1.77	3.60	0.63	15.12	1.75	2.72	2.33	2.97	3.57	99.58	0.22	0.21	<0.015	3.03	1.19	0.01	39.1
Ellis Township*	69.8	N.D.	3.8	0.58	13.5	2.09	1.46	2.48	2.15	2.7	98.7	N.D.	N.D.	0.01	N.D.	N.D.	0.79	N.D.

065. Granite and Anorthosite as Ceramic Raw Materials

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INTRODUCTION

The search for and characterization of deposits suitable as a source of ceramic raw material (Vos 1984, 1985) continued in 1986. Samples of leucocratic granite were collected in northwestern Ontario from deposits known to have a low iron content. Testing of these samples will show whether or not fractions of quartz and feldspar suitable for ceramic use can be obtained.

Requirements of the ceramic industry in production of glass, earthenware, whiteware, and advanced ceramics have been discussed previously (Vos 1984). The industry is primarily concerned with the purity and consistency of composition of its raw material. Production from large bodies of granite of uniform composition is favoured over the selective production of feldspar from pegmatite veins. The scale of operation brings an additional economic advantage to this approach.

PREVIOUS WORK

Chemical analyses of selected granites of the Westport map area from Vos (1985) are reproduced in Table 065.1. Granites represented by analyses 4, 5, 6, and 11 were tested by magnetic beneficiation and flotation media after crushing. These tests showed that, although a commercial feldspar product can be obtained, the granite as a whole will not permit economic production. The quartz fraction, forming from 20 to 30 weight percent of the rock, is not sufficiently iron-free to render sand of glass grade quality. Some of the impurities remain within the sand-sized grains, preventing reduction of the iron content below 0.10% Fe_2O_3.

However, similar contents of iron in the feldspar fraction (0.10 to 0.20% Fe_2O_3) do not exclude its use as a ceramic raw material, as iron contents of 0.35 to 0.50% Fe_2O_3 are acceptable in lower grade uses. In feldspar, a high content of potassium is desirable as it extends the firing range in which the required partial vitrification of ceramics takes place. By melting incongruently into glass (liquid) and leucite (solid), potassium feldspar allows the easy and gradual escape of gaseous components, according to Kuzvart (1984, p.171), causing minimal deformation of the fired product.

Analytical results obtained by X-ray fluorescence for various quartz and feldspar fractions of crushed granite, with or without magnetic beneficiation, are presented in Table 065.2. The iron contents of the magnetically beneficiated fractions of these samples were confirmed by atomic absorption analysis, as shown in Table 065.3.

An examination of the quartz and feldspar fractions by chemical analysis, X-ray diffraction and microscopy (Hicks 1986) showed the presence of several impurities, some of which could be the cause of iron contamination of the samples. They include chlorite, calcite, dolomite, sulphides, garnet, and iron oxide in the quartz fraction, and chlorite, tourmaline,

TABLE 065.1: ANALYSES (WEIGHT %) OF GRANITE NEAR LONG LAKE (2-7) AND CHARLESTON LAKE (11), WESTPORT MAP AREA. FROM VOS (1985).

	2	3	4	5	6	7	11
SiO_2	71.50	69.90	72.80	70.10	69.30	71.30	69.90
TiO_2	0.05	0.18	0.15	0.17	0.15	0.21	0.06
Al_2O_3	14.90	15.00	14.20	13.40	13.60	14.70	15.30
Fe_2O_3	0.07	0.22	0.15	0.36	0.29	0.22	0.29
FeO	0.27	0.39	0.17	1.33	0.77	0.68	0.52
MnO	0.01	0.01	0.01	0.01	0.01	0.0	0.01
MgO	0.27	0.39	0.17	1.33	0.77	0.68	0.52
CaO	2.67	2.67	1.66	3.32	2.58	0.51	1.00
Na_2O	3.24	2.39	2.10	2.33	2.04	1.63	2.40
K_2O	5.57	5.57	6.98	7.21	8.09	8.98	8.72
P_2O_5	0.01	0.01	0.01	0.02	0.0	0.04	0.0
CO_2	0.85	0.81	0.51	0.84	1.28	0.25	0.62
S	0.02	0.29	0.14	0.12	0.17	0.17	0.0
H_2O^+	0.33	0.36	0.17	0.18	0.31	0.53	1.82
H_2O^-	0.08	0.12	0.15	0.13	0.17	0.19	0.16
TOTAL	99.84	99.31	99.37	100.85	99.59	100.09	101.32
LOI	1.00	0.70	0.80	0.90	1.80	0.80	1.10
SP.GR.	2.58	2.58	2.58	2.60	2.60	2.58	2.58
TOTAL Fe: (as FeO)	0.33	0.59	0.30	1.65	1.03	0.88	0.78
TOTAL Fe: (as Fe_2O_3)	0.37	0.65	0.34	1.84	1.15	0.98	0.87

TABLE 065.2: X-RAY FLUORESCENCE ANALYSES OF QUARTZ AND FELDSPAR SEPARATES OF GRANITE SAMPLES FROM THE WESTPORT MAP AREA. ANALYSES BY THE GEOSCIENCE LABORATORIES, ONTARIO GEOLOGICAL SURVEY, TORONTO.

Sample		SIO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TIO_2	P_2O_5	MnO	Co_2	S	L.O.I.	Total
Quartz	001-4*	93.3	3.01	0.15	0.01	0.75	0.10	1.05	0.09	0.02	0.01	0.79	0.02	0.5	99.0
Feldspar	001-4*	64.6	19.0	0.19	0.00	0.34	2.40	11.3	0.07	0.05	0.00	0.38	0.01	0.5	98.5
Quartz	001-7*	95.5	2.17	0.04	0.00	0.67	0.00	0.37	0.06	0.03	0.01	0.69	0.01	0.6	99.4
Feldspar	001-7*	65.9	18.5	0.12	0.00	0.32	2.40	11.3	0.01	0.05	0.01	0.43	0.01	0.4	99.0
Quartz	002-3	80.0	9.59	0.54	0.60	1.97	1.44	4.48	0.26	0.03	0.01	1.14	0.08	0.9	99.8
Feldspar	002-3	67.1	17.9	0.01	0.03	0.66	2.65	10.3	0.06	0.02	0.00	0.81	0.02	0.9	98.4
Quartz	003-3	93.5	1.85	0.18	0.66	2.11	0.00	0.32	0.10	0.04	0.01	1.03	0.02	0.9	99.7
Feldspar	003-3	63.5	18.4	0.22	0.32	0.97	0.92	12.8	0.10	0.05	0.00	0.69	0.10	0.8	98.1
Quartz	004-3*	96.2	1.90	0.13	0.00	0.12	0.00	0.22	0.01	0.02	0.01	0.17	0.02	0.4	99.0
Feldspar	004-3	63.9	20.1	0.36	0.20	1.39	3.92	8.12	0.10	0.04	0.01	0.62	0.04	0.6	98.7

*non-magnetic samples

TABLE 065.3: IRON CONTENTS OF SELECTED QUARTZ AND FELDSPAR SEPARATES FROM GRANITE SAMPLES, WESTPORT MAP AREA. ANALYSES BY THE GEOSCIENCE LABORATORIES, ONTARIO GEOLOGICAL SURVEY, TORONTO.

		% Fe_2O_3	
Sample		**XRF**	**AAS**
Quartz	001-4	0.17	0.18
Feldspar	001-4	0.20	0.17
Quartz	001-7	0.10	0.13
Feldspar	001-7	0.15	0.16
Quartz	003-3	0.20	0.16
Quartz	004-3	0.16	0.13

iron oxide, pyrite, epidote, and carbonate in the feldspar fraction Extremely fine grained hematite, as dust-like inclusions in the sand grains, has been observed as well. It was concluded by Hicks (1986) that no single mineral is responsible for the iron content of the samples, but hematite could well be a principal contributor since its minor volume is offset by its large iron content.

SAMPLE AREAS

Two areas in northwestern Ontario were selected for sampling on the basis of existing geological reports and information from Resident Geologists in the area.

1. The Gullwing Lake granite northeast of Dryden was included in a study by Ucakuwun (1981). In a fourfold division of granitoid rocks, his "pegmatitic granites" are characterized by low contents of Sr and Ba and relative enrichment in Li, Rb, Cs, Be, Ga, and Y as illustrated in Table 065.4. They are considered parental to the mineralized pegmatites of the area in view of composition and spatial relationships.

   An estimate of the mineral content, based on outcrop and hand specimen, is given (Ucakuwun 1981, p.33) as 20 to 40% quartz, 0 to 50% K-feldspar, 2 to 80% plagioclase, 0 to 2% biotite, and 0 to 15% muscovite, with accessory garnet, tourmaline, beryl, and apatite. The anorthite content of the plagioclase should not exceed 5%, according to the published analyses.

   A 50 kg sample of pegmatitic granite was collected from outcrops southeast of Gullwing Lake, suggested by D.A. Janes, Resident Geologist, Ministry of Northern Development and Mines, Sioux Lookout. The granite is exposed in ridges of several tens of metres elevation, running in a

TABLE 065.4: ANALYSES OF GRANITES FROM THE GULLWING LAKE BATHOLITH. FROM UCAKUWUN (1981, p.41).

SiO_2 (wt.%)	75.10	74.05	76.50	76.20
TiO_2	0.05	0.05	0.07	0.02
Al_2O_3	14.86	14.56	13.40	13.76
Fe_2O_3	0.34	0.31	0.23	0.13
FeO	0.42	0.52	0.30	0.74
MnO	0.01	0.05	0.13	0.36
MgO	0.08	0.04	0.06	0.06
CaO	0.45	0.31	0.48	1.16
Na_2O	4.26	5.04	4.60	5.56
K_2O	3.44	3.87	4.03	1.33
P_2O_5	0.30	0.33	0.03	0.05
H_2O	0.84	0.54	0.31	0.41
CO_2	0.09	0.14	0.13	0.17
Total	100.24	99.81	100.27	99.95
Li (ppm)	62	28	6	50
Rb	200	286	458	111
Cs	2.5	1.8	4.6	5.5
Be	1.6	3.0	2.6	7.1
Sr	15	15	40	50
Ba	ND	ND	ND	ND
Pb	14	12	73	27
Ga	59	41	43	45
Y	14	11	56	64
Zr	22	44	63	34
Sn	19	11	16	5
Th	24	8	25	26
U	ND	ND	17	10
K/Rb	143	112	73	99
Rb/Sr	13.3	19.1	11.5	2.2
Al/Ga	1333	1880	1649	1618

TABLE 065.5: CHEMICAL ANALYSIS OF A SAMPLE PORPHYRITIC QUARTZ MONZONITE FROM THE OTTERTAIL LAKE STOCK.

	Weight %
SiO_2	74.0
Al_2O_3	14.5
Fe_2O_3	0.79
FeO	0.22
MgO	0.06
CaO	1.37
Na_2O	3.96
K_2O	4.27
TiO_2	0.09
P_2O_5	0.00
MnO	0.04
CO_2	0.11
S	0.01
H_2O^+	0.44
H_2O^-	0.07
L.O.I	0.6
Total:	99.9

northeasterly direction parallel to the lakeshore. Access is possible by lumber road. In view of the coarse grains (5 cm or more), chemical analyses will be obtained after separation of the quartz, feldspar, and mica fractions. Visual estimates of the mineral content correspond with data published by Ucakuwun (*see* above).

2. The Rainy River district is known for large bodies of felsic intrusive rocks. The Farrington Township and Bad Vermillion Lake areas were suggested by staff of the Kenora Resident Geologist's Office as possible sample sites. The presence of alaskite is referred to in the literature (Lawson 1913).

   In a study of the geology of the Mine Centre area, Wood *et al.* (1980) record the presence of partly metamorphosed, Early Precambrian, felsic intrusive rocks. A survey of the latter rocks along the shores and to the northwest of Bad Vermillion Lake, including Lawson's alaskite, showed that the metamorphic rocks lack the composition or uniformity required for economic operation. A substantial percentage of dark minerals and shearing and alteration of the feldspathic rocks detracts from their usefulness as a ceramic raw material. It was decided to forego collection of a large sample here in favour of a sample of massive leucocratic granitic rock from the Ottertail Lake Stock (Ontario Geological Survey, Map 2443, Geological Compilation Series) in Farrington Township. In the sample area, this stock consists predominantly of porphyritic hornblende-biotite quartz monzonite with K-feldspar phenocrysts. The sample, collected from outcrops along Highway 11, 15 km west of Mine Centre, is of grey to pink, medium-grained granitic rock with pink feldspar phenocrysts (1 cm in diameter). A chemical analysis of this rock is given in Table 065.5.

On the basis of this, and X-ray diffraction analysis, the following quantitative mineralogy was determined:

	weight %
Quartz	31
Albite	34
Anorthite	6
K-feldspar	22
Mica	5
Rest	2

Whether or not a potential for ceramic use exists can only be determined by analyses of sand-sized grains of quartz and feldspar after mineral separation.

RECOMMENDATIONS

Additional samples of granite should be collected from granite deposits in northwestern Ontario, preferentially those with a high potassium and low iron content.

When it has been ascertained that the most favourable deposits are represented, a selection of samples should be made for further analysis, mineral separation, and product evaluation.

The cost of this additional research prohibits any approach which is less than well organized and coordinated between the different regions of Ontario.

ACKNOWLEDGMENT

Don Janes, Resident Geologist, Ministry of Northern Development and Mines, kindly provided a vehicle for work in northwestern Ontario and accompanied the author to the Gullwing Lake granite. His share in collecting the sample was much appreciated. Mineral separation and beneficiation studies of Westport map area granites were done by A. Pindred, Department of Mining Engineering, Queen's University, Kingston.

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066. Precambrian Limestone Resources

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INTRODUCTION

The importance of carbonate in industry keeps limestone in the forefront of Ontario's industrial mineral production. Limestone is a source rock for calcium and magnesium metal, mineral filler and whiting, flux stone, building stone, soil conditioner, refractory material, road metal, construction aggregate, and cement and lime used in building and chemical industries. In 1984, the value of production of limestone and marble ($145.5 million) represented 81 percent of the total stone production in Ontario (Weatherson 1986), exceeding the value of sand and gravel by $9.5 million. The value is equal to 3 percent of the total Ontario mineral production. When the value added in manufacturing lime and cement, and calcium and magnesium metal is included, the limestone industry represents 11.5 percent of the total Ontario mineral production ($4.42 billion) in 1984.

A small but essential part of the limestone industry is based on Precambrian limestone resources. Production of magnesium metal is obtained by Timminco Limited from marble at Haley Station in the Ottawa River valley, and mineral filler and and whiting are produced by Steep Rock Calcite Division at Perth from Tatlock marble. Terrazzo chips and decorative marble aggregate are produced from several quarries in the Madoc area. Production of marble as dimension stone takes place occasionally.

Major Precambrian limestone quarries and prospects were examined in the 1986 field season in order to prepare a revision of Industrial Mineral Report 39 (Limestone Industries of Ontario). Precambrian limestone resources recognized in this revision include marble, carbonate veins, and carbonatite deposits.

MARBLE

Marble is the metamorphic equivalent of limestone. As a rule the grain size of marble indicates the degree of metamorphism. In the metamorphic process, plastic flow may occur, which may result in the separation of pure carbonate from a layered sediment. Details of this process were pointed out to the author by W. Meyer (Resident Geologist, Ontario Ministry of Northern Development and Mines, Sudbury). A large fragment of Espanola limestone in breccia northeast of the Sudbury Basin consists of alternating beds of siliceous silt and calcium carbonate. In one location this sequence can be seen to have been squeezed together, resulting in plastic flow of pure carbonate into a crosscutting fracture.

PARKIN TOWNSHIP

A body of calcite recently drilled in Parkin Township, 40 km north-northeast of Sudbury, is thought to have been emplaced by remobilization of Espanola limestone. Drilling has indicated a limited vertical extent to this lens-shaped body, and, based on outcrop and drill information, a possible total of 133 000 metric tons of carbonate is inferred (David Constable, geologist, Constable Consulting Incorporated, personal communication 1986). This total includes the fair and poorer grades of carbonate which surround good calcite. The calcite is milky white to transparent and very coarsely crystalline. Large crystals are frequently veined with buff grey impurities, partly along the cleavage planes. These impurities will be identified by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

Whether or not a small scale mining and processing venture can be based on this, and possible similar deposits locally, will depend largely on the success of developing special markets for material of high purity. As a possible source of raw material for stone craft and sculpting, the deposit has already drawn the attention of at least one Sudbury operator.

HALEY STATION

A dolomite quarry near Haley Station, 10 km northwest of Renfrew, is operated by Timminco Limited for the production of magnesium metal. A 76 m wide deposit of medium-grained, pure dolomite, striking northerly and dipping east at 55°, with an outcrop length of 1 km or more, is reported (Storey and Vos 1981). The quarry was temporarily inactive when visited in 1986, and information about the dolomite is incomplete.

TATLOCK

Two quarries in the Tatlock area (Lanark County), originally supporting building stone operations, are now part of the Tatlock Marble Property held by Steep Rock Resources Incorporated. Operations for production of calcite whiting and filler material proceed from the former Angelstone Quarry. The Omega Quarry lies to the north, and additional resources of low silica marble have been intersected by drilling to the west of the present quarry opening.

A visit to the quarry property, accompanied by Cameron Fox (consulting geologist, Steep Rock Resources Incorporated) served to correlate drill information with field observations. The major structure is a northerly striking marble belt dipping 40° to 70° eastward. In this belt, zones with low silica content (<3 percent) alternate with beds with a higher silica content. The low silica zone quarried at present reaches true thicknesses of 85 m. It is limited along strike and to the east by increased silica content, and to the west by impure dolomitic marble associated with increased silica content. Depth may be expected to exceed 100 m. The marble is white, calcitic, medium to coarse grained, free of graphite, and contains negligible phlogopite.

MATAWATCHAN TOWNSHIP

In the course of collecting information on major marble deposits, it was realized that little information exists on deposits in Matawatchan Township, northeast of the Madawaska River. Two days were spent in the area and several samples collected. The area is accessible by car from the Calabogie Road at a point 1300 m east of the Madawaska River crossing.

Marble in this area is largely coarse grained and graphitic. Although occasionally light grey or white rather than medium grey, the marble has little economic interest due to micaceous impurities and graphite content. Some of the samples collected will be tested chemically.

HUNTSVILLE AREA

Grenville marble is known from the Huntsville district. Several attempts to open marble quarries in this area have been undertaken in the past. A detailed survey of marble belts in the Parry Sound-Huntsville area is in progress (Marmont, this volume). Two days were spent in the field collecting marble samples and reviewing the extent of known marble outcrops. Satterly (1942) gives the following general description of crystalline limestone in the Parry Sound area:

> "Very little pure crystalline limestone occurs, and most of it is speckled with grains of silicate minerals. These are often arranged in lines or concentrated in zones or bands and indicate initial differences of composition between different laminae or beds of the limestone. In thin sections under the microscope, the rock consists of a mosaic of carbonate grains, in which are embedded rounded grains of serpentinized olivine, and diopside; in some localities purple spinel, phlogopite, tremolite, chondrodite, titanite, and apatite are also present. Where more sandy and shaly material was originally present plagioclase, quartz, biotite, hornblende, epidote, and scapolite are developed".

Commenting on amphibolite inclusions and silica content in numerous outcrops of crystalline limestone in fifteen townships, Satterly (1942, p.65) singles out four locations, respectively, in Christie, Ferrie, Lount and Ryerson Townships, where outcrops have a lower than usual percentage of impurities.

Detailed surveys will be necessary to outline the economic potential of marble in the district.

RECOMMENDATIONS

Precambrian limestones occur in the form of metasediments, calcite veins, and carbonatites. Any of these deposits can be a potential commercial source of carbonate. The many possible uses of carbonate require a complete physical, chemical, and aesthetic evaluation of the raw material. Chemical purity, colour, grain size, uniformity, structural soundness, and ease of mining will determine whether the deposit can be mined economically for local use or distant markets.

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067. Industrial Minerals of the Cargill Township and Martison Lake Carbonatite Complexes

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INTRODUCTION

Both the Cargill Township and Martison Lake carbonatite complexes are mantled by significant phosphate-rich residual deposits that probably developed during Late Mesozoic to Early Cenozoic time. The warm climatic conditions of the Late Mesozoic (Hallam 1985) and the spatial association of the Cargill residuum with kaolinite suggest that tropical to subtropical conditions prevailed during the period of major weathering of the parent carbonatite intrusions. These residual deposits contain concentrations of phosphate and other potentially economic materials that are far higher than the parent rocks. Their unlithified nature, closeness to surface, and large tonnages make them amenable to low-cost,open-pit mining. The aim of the current project is to document the mineralogy and chemistry of the two residual deposits, to compare and contrast them, and to determine, where possible, if any relationship exists between specific types of residuum and parent carbonatite. Exploration companies working on these deposits have filed extensive chemical and mineralogical data with the Geoscience Data Centre of the Ontario Geological Survey which will be incorporated into the present study.

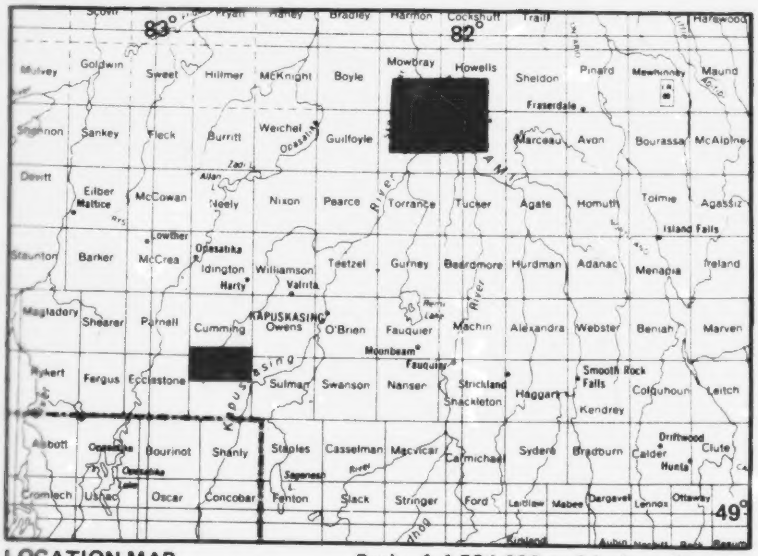
THE CARGILL COMPLEX

The Cargill Complex is located about 30 km southeast of Kapuskasing in northeastern Ontario, in the northwest corner of Cargill Township and the southwestern part of Cumming Township. The complex is accessible by forestry roads. It is one of several alkalic carbonatite complexes that lie within the Kapuskasing Subprovince of the Superior Province.

The Kapuskasing Subprovince is a narrow, northeasterly striking structural zone, characterized by positive magnetic and gravity anomalies, that transects the predominant easterly trending greenstone terrains (Thurston *et al.* 1977, Card *et al.* 1980). It is thought to be largely fault-bounded (Percival and Card 1985) and contains rocks of medium to high metamorphic grade.

PREVIOUS WORK

In 1954, Continental Copper Mines Limited identified the complex as a magnetic anomaly and subsequently drilled it as a base metal target. It was mapped by Bennett *et al.* (1967) and was included in a reconnaissance survey of carbonatite-alkalic complexes by Sage (1983a). Allen (1972) described the ultramafic rocks of the complex. Gasparini *et al.* (1971) studied the compositions of amphiboles and phlogopite at Cargill and Gittins *et al.* (1975) suggested that phlogopite associated with pyroxenite was a product of fenitization by alkali-rich fluids derived from the carbonatite magma. Twyman (1983) studied the petrography and mineral chemistry of calcitic carbonatite (sovite) from Cargill as part of a study of carbonatite magma genesis and differentiation. Sandvik and Erdosh (1977) discussed the results of International Minerals and Chemical Corporation Limited's exploration program on the phosphate residuum. Vos (1981) evaluated the potential of the complex for phosphate and other industrial minerals, including vermiculite and kaolin.


83°
82°
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Goldwin
Sweet
Hillmer
McKnight
Boyle
Mowbray
Howells
Sheldon
Pinard
Maund
Fraserdale
Sankey
Fleck
Burritt
Weichel
Guilfoyle
Marceau
Avon
Bourassa
McAlpine
Eilber
McCowan
Neely
Nixon
Pearce
Torrance
Tucker
Agate
Homuth
Tolmie
Agassiz
Island Falls
Barker
McCrea
Opasatika
Idington
Williamson
Teetzel
Gurney
Beardmore
Hurdman
Adanac
Menapia
Ireland
Shearer
Parnell
Cumming
KAPUSKASING
Owens
O'Brien
Fauquier
Machin
Alexandra
Webster
Beniah
Marven
Moonbeam
Fergus
Ecclestone
Sulman
Swanson
Nansen
Strickland
Shackleton
Haggart
Smooth Rock Falls
Kendrey
Colquhoun
Leitch
Bourinot
Shanly
Staples
Casselman
Macvicar
Carmichael
Sydere
Bradburn
Calder
Driftwood
Hunta
Clute
Oscar
Concobar
Fenton
Slack
Stringer
Ford
Laidlaw
Mabee
Dargavel
Lennox
Ottaway

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

EXPLORATION HISTORY

The Cargill property was first staked in 1954 by Continental Copper Mines Limited (CCM), which carried out a magnetometer survey, followed by diamond drilling and trenching in 1955. Kennco Explorations (Canada) Limited optioned the property in 1965 to look for copper-nickel mineralization but soon after dropped its option (Sage 1983a). Union Carbide Canada Mining Limited staked the ground to the west of Continental Copper's property in 1969, and reported up to 17 percent apatite in the carbonatite but only minor copper-nickel mineralization. In 1970, Kennco again optioned CCM's property, staked additional adjoining claims, and carried out a limited diamond-drilling program. Only minor copper-nickel mineralization was found in the ultramafic rocks of the complex.

In 1974, as part of a search for phosphate deposits, the International Minerals and Chemical Corporation Limited optioned Continental Copper Mine's ground and staked additional claims at Cargill. They drilled some 190 boreholes, mainly by reverse circulation, carried out several thousand chemical and mineralogical analyses, and did a preliminary feasibility study and metallurgical testing (Sandvik and Erdosh 1977).

The Cargill property was optioned by Sherritt Gordon Mines Limited in 1979. A further 82 holes were drilled using roto-sonic equipment. The company carried out metallurgical testing, along with a preliminary pit design and new ore reserve calculations. Ore reserves were estimated to be 33 million tonnes for the entire deposit at a grade of 25.3 percent P_2O_5 with more than 20 million tonnes at 27.5 percent P_2O_5 in the zone of the proposed pit. A pilot pit was excavated at the south subcomplex, and, in 1985, a small mill was set up to provide a large bulk sample. The project is presently inactive.

GEOLOGY

The complex has a distinct, dumbbell-shaped aeromagnetic signature (ODM-GSC Map 2252G) with two major positive anomalies, aligned roughly northeast-southwest, called the north and south subcomplexes (Sandvik and Erdosh 1977). The intensity peaks of the two anomalies are about 3.7 km apart; the southern anomaly is the stronger of the two with maximum intensity of about 69 500 gammas above a background of 59 to 60 000 gammas. There is a subsidiary anomaly about 3 km west of the southern peak.

The intrusion consists of Early Proterozoic carbonatite and ultramafic rocks hosted by Archean quartz diorite gneisses, amphibolites, and granitic gneisses (Sandvik and Erdosh 1977, Sage 1983a). Gittins *et al.* (1967), based on Ar-dating of biotite, placed the time of intrusion of the Complex at about 1.8 Ga. Sandvik and Erdosh (1977) suggested that the two subcomplexes resulted from displacement of the halves of a single intrusive body along a north-northeasterly striking dextral fault.

The south complex has a zoned core of carbonatite partly rimmed by ultramafic rocks which range from olivine clinopyroxenite to amphibole rock (Sage 1983a). The work of Twyman (1983) suggests that the ultramafic suite and the carbonatites are not comagmatic. Field relationships indicate that the carbonatites are younger than the ultramafic rocks. The carbonatite suite is composed of calcite carbonatite (sovite), dolomite carbonatite (rauhaugite), and siderite carbonatite (Sandvik and Erdosh 1977). However, the siderite carbonatite has only been identified in what Sandvik and Erdosh (1977) call leached carbonatite. Sage (1983a) and Twyman (1983) have also described silicocarbonatites (hybrid carbonatites): rocks with less than 50 modal percent carbonate minerals. Petrographic descriptions of these rock suites may be found in Allen (1972), Sage (1983a), and Twyman (1983). Zonation within the complex appears to be vertical or subvertical (Sandvik and Erdosh 1977, Sage 1983a).

The carbonatites can be further subdivided on the basis of accessory minerals (Twyman 1983). Common accessory minerals are sodic amphiboles (arfvedsonite and richterite), phlogopite, olivine, magnetite, and apatite. Apatite content in sovite ranges from 7 to 15 weight percent with a mean of 10 weight percent (±4.0 weight percent). In rauhaugite, the mean apatite content is 14.4 weight percent(±5.8 weight percent), varying between 9 and 30 weight percent. As seen in thin section, apatite crystals are ellipsoidal or barrel-shaped with only sparse euhedral and subhedral grains, up to 1 mm in diameter, and are fairly typical of primary igneous fluorapatite. However, up to 10 percent of the apatite grains are biaxial (positive) which suggests the possibility of partial substitution of PO_4 radicals, probably by CO_3. Electron microprobe study on the compositions of primary apatites may confirm this hypothesis.

RESIDUUM GEOLOGY

The Cargill phosphate deposit is a residuum developed by chemical weathering of the otherwise subeconomic carbonatite. Based on the palynology of an organic-rich sample (Sage 1983a), the time of major residuum development has been estimated as Late Cretaceous to Early Tertiary. The thickness is variable, ranging from a few metres to more than one hundred metres. It is thickest in troughs on the buried bedrock surface that appear to trend northeast. The residuum consists of unconsolidated silt to sand-sized material, composed largely of apatite with variable amounts of goethite, sulphide minerals, magnetite, and traces of carbonate minerals.

Sandvik and Erdosh (1977) identified crandallite (a Ca-Al-hydroxyphosphate of the plumbogummite group) as the major phosphate mineral in a thin zone in the upper part of the residuum. Enrichment in rare earth elements (REE) was noted in this "crandallite blanket". Crandallite and its isostructural counterparts can readily accomodate large cations, such as lanthanides, in open, twelve-fold coordination sites (Altschuler 1973) and it is probably the major REE-bearing phase. In general, the Cargill deposit does not contain significant amounts of rare earth elements or niobium, and minerals such as monazite and pyrochlore have not been reported.

Sherritt Gordon Mines Limited have a simple, colour-based field classification for the residual material ("ore"): light to medium grey, red (reddish brown), brown, and black. However, semiquantitative X-ray diffraction data indicate that these four types generally have the same mineral assemblages, which occur in different proportions. The grey "ore" is largely an apatite sand and probably is the most attractive ore material, both in terms of grade and ease of beneficiation. The black "ore" may contain significant amounts of organic material which can cause difficulties in processing. Crandallite occurs mainly in the black material, but traces of this mineral occur in several samples of the other three types.

There is a transitional zone from fresh carbonatite to unlithified residuum, that is referred to by Sandvik and Erdosh (1977) as "leached carbonatite". The material in this zone consists of soft, crumbly rock with abundant apatite and goethite (Sandvik and Erdosh 1977). This transitional zone is discontinuous and ranges in thickness from a few to over one hundred metres. Chemical data from International Minerals and Chemical Corporation Limited suggest that there are two types of "leached carbonatite": one with fairly high P_2O_5 content (averaging 15 to 18 percent and as high as 34 percent) and the other with a markedly low P_2O_5 content (around 5 to 6 percent). In the case of the low P_2O_5 material derived from dolomitic carbonatite, the corresponding MgO values are high (around 16 weight percent). This is not the case for the high P_2O_5 material, in which MgO levels are commonly less than one percent. Corresponding semiquantitative X-ray diffraction data indicate medium to major amounts of dolomite and calcite in the low P_2O_5 materials. Goethite is abundant in both types. This suggests that the low phosphate material is partly weathered carbonatite. The high phosphate material may be a weakly cemented residuum, analogous to cemented residua at Finland's Sokli Complex (Vartiainen and Paarma 1979) and at Martison Lake (see below). Unfortunately no samples of leached carbonatite are presently available.

During the fall of 1985, Sherritt Gordon Mines Limited's pilot pit was examined by the author. Exposed Quaternary overburden consists of clay to silt till, up to 2 m thick, overlain by up to 10 m of rhythmically stratified (varved) silt and clay. At the western end of the pit, there are up to 2.5 m of ripple-marked sand between the till and the varved sediments. The only "preglacial" sediments exposed are in a small lens (<5 m long) near the centre of the pit and consist of kaolinitic silica sand, lignite, and minor ball clay.

The residuum is highly variable in colour and texture. Grain size ranges from silt to silty sand and colour varies from yellowish orange to dark greyish brown. Locally, irregular, contorted colour and grain-size banding is present. In the dark-coloured residuum, yellowish "limonite" streaks are common, as are cemented nodules (up to 4 cm in diameter) and highly micaceous (vermiculite?) zones.There are numerous thin stringers of white to very light grey clay in the residuum and irregular patches of mottled light grey apatitic sand near the centre of the pit. In places, the overlying glacial till shows incorporation of residual material.

Preliminary X-ray diffraction and microprobe studies have been carried out on a small suite of samples from the pit. Processed material from the mill stockpile was also analyzed using X-ray diffraction. Specific phosphate mineral types could not be identified in the pit samples. The grey "ore" contains both fine and coarse-grained Ca-phosphate (apatite?), up to one percent Mn-bearing ilmenite, and, in the fine fraction, quartz, kaolinite, limonite (goethite), and minor hematite. A Ca-Al-Fe phosphate (crandallite?) forms the fine-grained matrix of a sample of black ore. Both samples of the concentrate are high in apatite (>90 percent) with minor mica, calcite, kaolinite, and possibly dolomite and amphibole. Crandallite is present in one sample and zircon and baddeleyite are present in the heavy mineral separate.

Microscopic examination of the coarse concentrate reveals abundant apatite with minor phlogopite, sand-sized clay aggregates, and traces of ilmenite and amphibole. The apatite grains fall into three classes:

1. clear ellipsoidal and barrel-shaped grains, many with visible mineral inclusions
2. cloudy ellipsoidal grains
3. grains, partly or completely overgrown by secondary phosphate minerals

Subsamples of the clear and overgrown grains are presently awaiting microprobe analysis.

MARTISON LAKE COMPLEX

The Martison Lake Carbonatite Complex lies in the southern part of the James Bay Lowlands, about 70 km north of Hearst, at 50°20′N latitude, 83°25′W longitude. Access is only by air or winter road. The area is almost continuous muskeg and is blanketed by Quaternary sediments. There are no bedrock exposures.

PREVIOUS WORK

Satterly (1968) suggested that the aeromagnetic anomalies at Martison Lake might be a carbonatite-alkalic rock complex. Niobium and phosphate were found in an early drill hole by Uranium Ridge Mines Limited, and were mentioned by Ferguson (1971) in a compilation report on columbium (niobium) deposits in Ontario. Sage (1979) recommended drilling the Martison Complex to investigate residual phosphate deposits. A brief summary on the complex was included in a report on alkalic complexes of the James Bay Lowlands by Sage (1983b). A thesis study by Hart (1983) focused on the mineralogy of the residuum and the weathered carbonatite.

EXPLORATION HISTORY

In 1965, a group of exploration companies, led by Uranium Ridge Mines Limited, bored a diamond drill hole to test an electromagnetic (EM) conductor associated with a circular magnetic anomaly in the area. The inclined, 166 m hole did not reach bedrock but the lower 57 m were in magnetite-rich sand. Secondary phosphate minerals, titaniferous magnetite, and other iron oxides were found in a piece of boulder encountered at 109 m.

In 1967, 98 claims were staked in the area for an unknown party and a low level aeromagnetic survey was carried out and filed for assessment. Shell Canada Resources Limited staked a total of 346 contiguous claims in the area in 1980 and 1981. Geophysical work, including an airborne survey and seismic testing was done in 1981, along with a drilling program consisting of 554 m distributed over five holes. In 1982, this was followed by the drilling of 37 holes, mainly using reverse circulation techniques, and metallurgical testing of a small bulk sample. The property was subsequently taken over by Camchib Resources Incorporated, which conducted a program of sonic and reverse circulation drilling, geotechnical and hydrogeological studies.

GEOLOGY

Because of the absence of outcrop, the bedrock geology of the Martison Lake area is poorly understood. No Paleozoic rocks have been found in any drill holes in the area and in holes that have reached the bedrock only carbonatite has been encountered. The complex is assumed to be hosted by Archean rocks of the Superior Province but their lithology here is unknown. The complex is west of the Kapuskasing Structural Zone.

The aeromagnetic signature of the complex consists of two roughly circular positive anomalies of about 5000 gammas peak intensity above a background of around 4200 gammas (*see* ODM-GSC Map 3960G). The larger northern anomaly (subcomplex A) is about 4 km in diameter. There is a smaller elliptical anomaly (subcomplex C) southeast of subcomplex A. This suggests that there are three separate intrusions.

Most of the drill holes at Martison Lake have not cored the bedrock, and information on the nature of the lithologic character of the carbonatite is very limited. Petrographic examination of a limited number of samples, which were supplied by Camchib Resources Incorported, provide preliminary information on the carbonatite lithology. The unweathered carbonatites consist largely of dolomite, with accessory ankerite, apatite, phlogopite, pyrochlore, and oxide minerals. Oxides include goethite and hematite, which in places form hematite pseudomorphs after magnetite. Sulphide minerals, mainly pyrite, are abundant in brecciated carbonatite. Moderately developed foliation, suggestive of shearing, is present in two thin sections. Much of the carbonate appears to be recrystallized, and crystal size distribution in the foliated sections is distinctly bimodal. In unweathered carbonatite, apatite crystals are ellipsoidal to euhedral and up to 0.5 mm in diameter. About 10 percent of the apatite is biaxial (*see* previous discussions in the section on Cargill).

RESIDUUM GEOLOGY

The residual material is variable in size, ranging from clayey silt to silty sand, with colour from light yellowish brown to dark brown. Apatitic sand, similar to Cargill's "grey ore", appears to be relatively uncommon. The fine-grained materials are mainly clay minerals, goethite, magnetite, and siderite. The sand and coarse silt fraction is made up of fluorapatite, francolite (carbonate fluorapatite), magnetite, goethite, ilmenite, pyrochlore, and columbite. Florencite ($CeAl_3(PO_4)_2(OH)_5$) and crandallite have also been found in the coarse fraction. Other minerals mentioned in reports by Camchib Resources Incorporated include woodhouseite ($CaAl_3(PO_4)(SO_4)(OH)_6$), waylandite ($(Bi,Ca)Al_3(PO_4)_2(OH)_6$), phlogopite, vermiculite, barite, fluorite, maghemite, chlorite, feldspar, amphibole, zircon, and bastnasite.

The "cemented residuum" is the lithified equivalent of the loose residuum. It occurs as fragments and blocks within the unlithified residuum ranging from a few centimetres to tens of metres in size. The cement is a mixture of goethite and a white, translucent mineral. Hart (1983) tentatively identified this mineral as francolite, the abundant secondary phosphate of the residual deposit at the Sakli Complex (Vartiainen and Paarma 1979). X-ray diffraction data from the present study indicate the material is an apatite; probably, but not conclusively, francolite. The francolite makes up 40 to 70 percent of the cemented residuum and occurs not only as a cement but also as botryoidal crusts in cavities.

The age of the Martison Lake residuum is inferred only from the presence of overlying clastic sediments interpreted to be correlative with the Mattagami Formation. Palynological work by Norris (1982) indicates that deposition of the Mattagami Formation took place during Middle to Late Albian (latest Early Cretaceous). This suggests an earlier time of formation for the Martison Lake residuum than the Cargill deposit; clearly further work is required to establish the age of the deposit.

USE OF PHOSPHATE

The principal use of phosphate is in the manufacturing of superphosphate fertilizers. Production of these fertilizers requires phosphoric acid, which is made industrially by reacting apatite with sulphuric acid, with gypsum as a by-product. This process provides a use for metallurgical sulphuric acid. Recently, workers at Agriculture Canada have begun research into composting apatite concentrate from Cargill with peat and other organic materials to produce a low cost fertilizer (Mathur *et al.* 1986). The principal problem is to produce a material with soluble phosphorus in a form that is readily available for use by plants. Preliminary results indicate a high degree of induced solubility with more phosphorus available to crops than from phosphorus provided by sedimentary "phosphate rock" or even superphosphates.

Another possible use for apatite concentrate is as a substitute for bone ash in bone china. Successful use in china will depend, in part, on reducing the iron and titanium content of the concentrate to levels that will allow a satisfactory white colour after firing. This is currently being studied by staff of the Mineral Resources Branch of the Ministry of Northern Development and Mines (Duncan Ash, Geologist,Mineral Resources Branch, Ontario Ministry of Northern Development and Mines, personal communication 1986).

OTHER COMMODITIES

At Cargill, large amounts of kaolin, mainly mixed with quartz sand in the "preglacial" overburden, have been found. In places this material is up to 22 m thick (Sandvik and Erdosh 1977), but its distribution is somewhat irregular. A sample of the kaolinitic silica sand from the pilot pit was analyzed and found to contain 39 percent silt- and clay-sized materials. The Fe_2O_3 content of this fine fraction is 0.6 percent and TiO_2 content is 2.3 percent. From the chemistry and X-ray diffraction analyses, the kaolinite content is estimated to be 95 percent, and only minor amounts of quartz are present. Anatase is the titanium-bearing mineral. The ceramic properties of the Cargill kaolinite are being tested and it could be a valuable by-product of phosphate production.

Vermiculite, useful as a horticultural soil conditioner and as an expanded filler and insulating material, is present at Cargill along the contact between the ultramafic suite and the carbonatite (Sandvik and Erdosh 1977, Vos 1981). It is the product of the weathering of phologopite. The vertical extent of the vermiculite is largely untested.

Significant amounts of niobium are present in the Martison Lake residuum and it could be a valuable by-product. Camchib Resources Incorporated data indicate sample levels as high as 2.5 weight percent but average values are generally less than one percent. Pyrochlore, a primary igneous phase, is the only identified niobium-bearing mineral.

DISCUSSION

The presence of secondary phosphates at Martison Lake (francolite) and Cargill (crandallite) suggests fairly advanced and intense chemical weathering. Dissolution of apatite requires low pH conditions (Altschuler 1973) and hence complete removal of buffering carbonates. Precipitation of francolite probably reflects higher pH conditions further down the weathering profile from areas of active dissolution. The formation of crandallite requires the addition of aluminum, which may have been provided at Cargill by the breakdown of aluminous silicates in the preglacial sediments. The kaolinite in these sediments probably resulted from *in situ* kaolinization of feldspars, especially where kaolinite is mixed with silica sand.

Currently, selected suites of samples from both complexes are being analyzed for mineralogy, major oxides, and trace elements, including lanthanides, U, Th, and Nb. These data will supplement existing data, all of which will be used for multivariate statistical analyses. It is hoped that mineralogical and chemical zonation, if present within these deposits, will be found with systematic analysis of the data. Mineral assemblages should give valuable information on the conditions of residual formation.

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068. Industrial Minerals and Rare Earth Element Deposits in the Muskoka-Parry Sound-Nipissing Area

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Regional and Economic Development Agreement (ERDA) signed by the governments of Canada and Ontario.

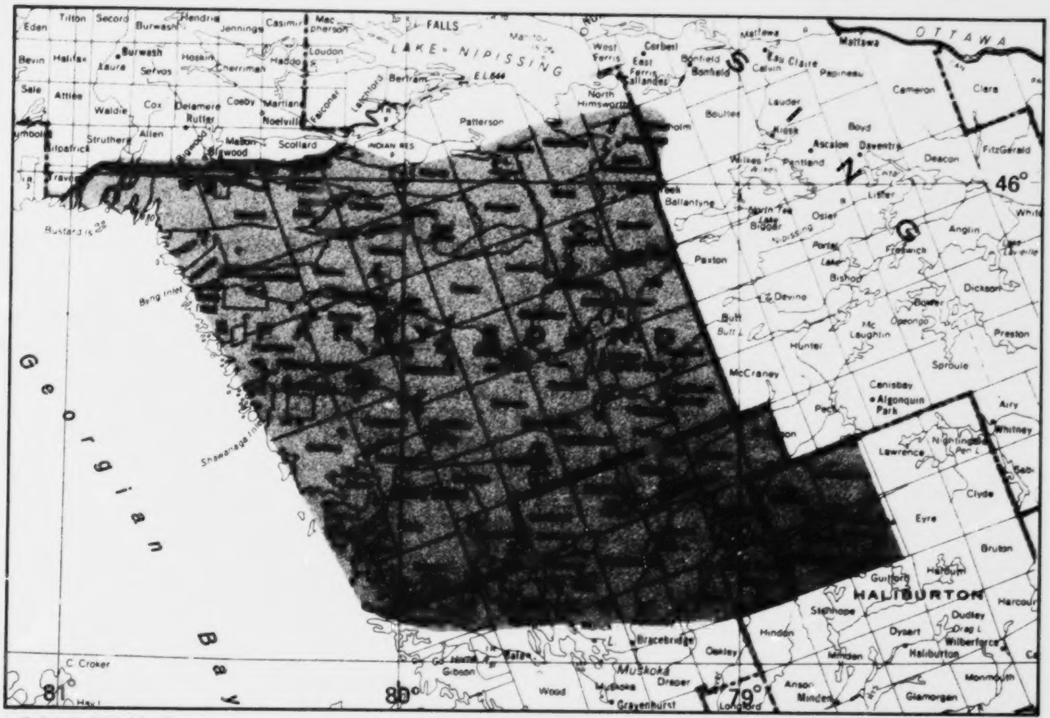
INTRODUCTION

The project is designed to evaluate the industrial mineral and rare-earth element potential of the western part of the Muskoka-Parry Sound-Nipissing area. This is a three-year project initiated in the Spring of 1986, and scheduled for completion in 1989.

The project area is bounded to the north by the French River and Lake Nipissing, to the east by the western boundary of Algonquin Park, to the west by Georgian Bay, and to the south by the Lake Muskoka recreational area.

The objectives of the program are:

1. To test known occurrences of anorthosite for their potential use as a source of high-alumina ceramic material, as a potential host for titanium or vanadium, and, theoretically, as a source of aluminum. Additional elements of interest might be phosphorus, chromium, manganese, and platinum group metals; some varieties of anorthosite have potential as a source of building stone.
2. To re-evaluate known occurrences of marble as a potential source of basic refractories, and for use in the filler industries as a flux, and as a source of lime. Some varieties may have possibilities for use as building or decorative stone. Associated minerals with economic potential include talc and tremolite. Some occurrences are believed to be dolomitic.
3. To investigate pegmatite occurrences as a source of rare earth elements, high purity silica, and potash feldspar.
4. To evaluate various rock types as sources of stone for use in a variety of applications in the building and construction industries and as decorative and ornamental stone. In part, this study overlaps with the marble and anorthosite programs, but will also be concerned with granites (*sensu lato*), late mafic intrusions (black granite), and gneisses. This aspect of the program overlaps with the COMDA Mid-Ontario Building Stone Project.
5. To investigate the occurrence of other industrial rocks and minerals reported in the western part of the Central Gneiss Belt and evaluate their economic potential. Graphite is one of the more



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

promising targets in the project area; other mineral occurrences of potential interest reported in the area include garnet and kyanite.

6. To disseminate the findings of the study with the intention of stimulating the development of both local use of industrial rocks and minerals and, hopefully, some exporting capacity.

The program will detail the geology of known mineral deposits and occurrences, appraise their economic potential, and provide a base of lithochemical and, where appropriate, physical characteristics of the industrial rocks and minerals of the area. Results will be published in annual progress reports in the Spring of 1987 and 1988, with a final report in 1989. This work will be coordinated with ongoing geological mapping programs conducted by the Precambrian Geology and Engineering and Terrain Geology Sections of the Ontario Geological Survey.

MINERAL EXPLORATION

The Muskoka-Parry Sound-Nipissing area does not have a strong history of mining activity or mineral exploration. Many occurrences dsa prospects of metallic and industrial rocks and minerals are described in the publications of Satterly (1942, 1943a, 1943b) and Hewitt (1964b, 1964c, 1967a, 1967b) and of industrial rocks and minerals, in the report of Martin (1983). Marble occurrences have also been described in several publications describing Ontario's limestone industry (Goudge 1938; Hewitt 1960, 1964a). There was limited gold and base-metal production in the Parry Sound area early in the century.

Industrial mineral production in the area has been limited to: building stone (flagstone); the burning of marble for lime; quartz, mica, and potash feldspar production from pegmatites at the turn of the century; and production of diatomite. In the 1960s and 1970s some marble occurrences were tested as potential sources of high purity calcite. Pilot beneficiation tests are reported to have generated a product of high purity, but no commercial production was achieved. Since the second world war, several pegmatites have been tested for uranium, but mineralization appears to have been of low grade and erratic distribution. Allanite and apatite are components of many pegmatites in the area and may represent sources of rare-earth elements.

Flagstone production is currently the only significant commercial enterprise in the area, primarily from the Mill Lake Quarry near Parry Sound. Several graphite occurrences have been known for many years, and some are currently the focus of exploration activity. At its Butt Township property, Cal Graphite Corporation has recently published reserves of 17 million tons with an average grade of approximately 3 percent (by weight) flake graphite, and is in the course of conducting a feasibility study (Cal Graphite News Release, July 4th, 1986; Garland, in press). In 1985, a zoned pegmatite occurrence in Murchison Township was tested for its silica potential, and a pegmatite was staked for its samarium potential in the northwestern part of the project area (Villard and Garland 1986). In Chapman Township the Blue Star Mine, an amazonite-bearing pegmatite, is currently being operated as a tourist and mineral collecting site.

GENERAL GEOLOGY

The geology of the Parry Sound-Muskoka-Nipissing area is poorly understood. Geological maps of the area are limited to small scale maps that resulted from a series of unrelated programs. They comprise Satterly's map at a scale of 1:126 720 (1 inch to 2 miles) (Satterly 1943a), Hewitt's map of the southern half of the project area at a scale of 1:126 720 (1 inch to 2 miles) (Hewitt 1967a), and Davidson's 1:253 440 (1 inch to 4 miles) scale map (Davidson 1982). All of these maps were produced as a result of programs which were essentially of a reconnaissance nature. Van Berkel and Schwerdtner (1986) mapped the Moon River Synform at a scale of 1:50 000. Lount Township was mapped by Satterly in 1955 at a scale of 1:31 680 (1 inch to 1/2 mile) (Satterly 1956). Trussler and Villard (not published, these are field maps done in the 1970s and are not even in manuscript form) have mapped an area south of Parry Sound at a scale of 1:31 680 (1 inch to 1/2 mile); although not published, their map is available. Adams and Barlow (1910) Lumbers (1971, 1975) and Wynne-Edwards (1972), amongst others, have discussed the geology of the region. Several theses have been completed on aspects of the geology of the Whitestone anorthosite The geological database for the area is therefore far from complete. E.G. Bright (this volume) is currently mapping parts of Croft, Ferrie, Hagerman, and McKenzie Townships at a scale of 1:15 840 (1 inch to 1/4 mile) and further mapping is planned for the next two years of the COMDA agreement.

The project area lies within the Central Gneiss Belt of the southwestern Grenville Province. The dominant lithology is quartzo-feldspathic gneiss, with lesser amounts of hornblende gneiss, quartzite, and marble. These have been metamorphosed to amphibolite and granulite grade, and commonly display evidence of severe deformation. The most recent attempt to synthesize the geology of the area is that of Davidson and coworkers (Culshaw, Davidson, and Nadeau, 1983; Davidson and Morgan 1981; Davidson *et al.* 1982, 1985; Davidson and Grant 1986), who have defined a number of domains and subdomains, each having distinctive lithological, structural, and metamorphic characteristics which are truncated at domain boundaries. The domain boundaries are interpreted as ductile shear zones formed by the northwesterly directed thrusting of one domain over another.

Most of the known metallic and nonmetallic mineral occurrences occur within the Parry Sound Domain, which is characterized by abundant hornblende gneiss, marble, and quartzite. This domain extends from south of Parry Sound and northeastward to Commanda. The western part of this domain contains several large bodies of gabbroic anorthosite and anorthosite. Outside the Parry Sound Domain, most known "occurrences" (Martin 1983) consist of building stone (gneisses and late mafic intrusions), pegmatites, and graphite. With few exceptions, good documentation of the occurrences, their geological controls and setting, are lacking.

CURRENT PROGRAM

The current year's field work is directed primarily toward the reconnaissance of previously identified targets, such as anorthosite, selected marble, and pegmatite occurrences, potential dimension stone sites, a cross section of mineral occurrences, and an overview of the regional geology. This will help establish priorities for the remainder of the program.

Reconnaissance traverses have been completed over the Whitestone and Arnstein anorthosite bodies, and samples have been collected for analysis. The Whitestone anorthosite is tadpole-shaped in plan; some 7 km wide at its widest point, and over 25 km long. Its marginal phases are strongly sheared and of gabbroic anorthosite composition, containing garnet and/or epidote. Toward the centre, anorthosite becomes prevalent and often consists of medium- to coarse-grained plagioclase with clinopyroxene oikocrysts up to 30 cm in diameter (Mason 1969). It is generally massive, with minor local shear zones in contrast to the more penetrative deformation of the marginal areas. Compositional banding can be seen in several locations and appears to be a primary texture. Sulphide mineralization is rare, but pyrite, pyrrhotite, and chalcopyrite grains occur locally. However, a few percent of disseminated pyrite has been seen in smaller bodies of anorthosite east of the Whitestone body (E.G. Bright, Geologist, Ontario Geological Survey, Toronto, personal communication, 1986). Magnetite and hemo-ilmenite are disseminated throughout the marginal parts of the body in amounts of from 1 to 3 percent, but are less abundant in the central part. The magnetite is a low titanium variety.

The Arnstein anorthosite is a crescent-shaped body, convex to the northwest, which extends northerly and easterly from near the northern end of the Whitestone anorthosite. It is 25 km long and up to 5 km wide. It is extremely deformed and exhibits intensive shearing and tight mesoscopic isoclinal folding. In overall composition it appears to be a gabbroic anorthosite or leucogabbro.

No further work is planned on the anorthosites during 1986, but follow-up programs are anticipated in 1987.

Several pegmatite bodies have been mapped and sampled in Conger and McDougal Townships. Several are former minor producers of mica, potash feldspar, and quartz; three contain radioactive minerals, including allanite crystals up to 15 cm long. Future work will attempt to establish the geological controls of pegmatite occurrences, and to determine the distribution and potential of economic mineral phases.

Marble pits in Hagerman and Spence Townships, which had been tested in the past for their calcite content, were mapped in detail and sampled. Several other minor occurrences were sampled. All of the marble seen to date is a tectonite consisting of coarse-grained calcite, with lesser dolomite, containing disseminated silicate minerals such as diopside, tremolite, olivine, chondrodite, and graphite, as well as large inclusions of amphibolite, pegmatite, quartzite, and gneiss. Further work will be directed toward mapping the distribution of the marble units and determining which areas contain relatively pure carbonate, and whether such material can be readily beneficiated to a desirable product.

At the time of writing (early September) some two months remain in the field season. It is planned that this time will be devoted to reviewing various mineral occurrences, to a preliminary evaluation of potential dimension stone sites—notably the Powassan Batholith and late metagabbroic intrusions—and other favourable building stone sites previously defined by Verschuren *et al.* (1986), and to general reconnaissance of the whole project area.

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069. The Paleozoic–Precambrian Unconformity and Associated Mineralization in the Madoc Area (Eastern Ontario)

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

The Paleozoic-Precambrian unconformity in eastern Ontario is spatially associated with occurrences of vermiculite, oxide ores of iron and gold, and vein deposits containing fluorite, barite, lead-zinc, and strontium minerals (Springer 1985). The unconformity, which extends from Midland on Georgian Bay to Kingston on Lake Ontario, therefore provides a broad target for other such deposits. This summary presents results of the first year of a program to document the areal distribution of the unconformity, locate and describe all associated mineralization, and determine the role of the unconformity in the formation of this mineralization in eastern Ontario.

The area selected to begin this work is centred on the Town of Madoc, and includes Madoc Township, the eastern extremity of Marmora Township, and the northern part of Huntingdon Township. It extends from the community of Queensborough, in the east, to Deloro, in the west, and from Bannockburn, in the north, to Crookston in the south. Highway 7 crosses the area from east to west, and Highway 62, from north to south. All parts of the area are easily accessible by road.

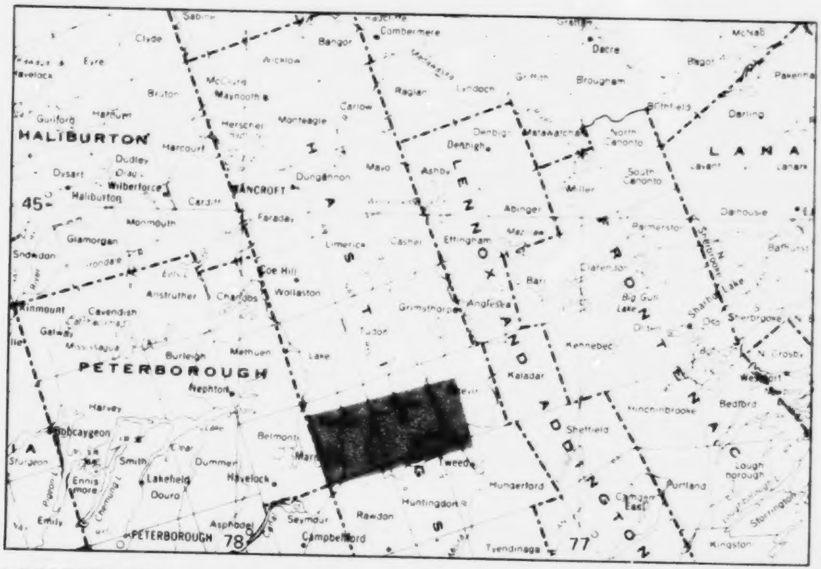
This area is transected by the unconformity, and has been a centre of mining activity since the mid 1800s. Although talc is the only commodity still being mined in the area, past-producing mines were worked for fluorspar, barite, calcite, iron, copper, lead, zinc, gold, and talc. The 1986 field program comprised: (a) locating and describing all exposures of the unconformity surface, especially around Paleozoic outliers; and (b) examining, sampling, and describing some mineral occurrences in order to understand their relationship to the unconformity surface.

THE PALEOZOIC–PRECAMBRIAN UNCONFORMITY

DESCRIPTION

The land to the north of the Paleozoic-Precambrian contact in the study area forms part of the Precambrian peneplane and constitutes the meridional part of the Grenville Province. The Tudor volcanics, Hastings-type marble, metaconglomerate, schists, and volcanics, and four main bodies of pink granite and syenite constitute the principal rocks of the Precambrian in this area (Figure 069.1).

South of Moira Lake, the area is underlain by the Black River limestones of Ordovician age. Flat-lying outliers of these Paleozoic rocks are common in the northern part of this area. The basal member of the Black River series is in contact with the Precambrian surface. This basal member, which can take several names (Shadow Lake Formation, mixed unit, rough basal sandstone), consists mainly of more or less


HALIBURTON
PETERBOROUGH
LANA
Clyde
Bangor
Combermere
Dacre
McNab
Eyre
Havelock
Wicklow
McClure
Maynooth
Bruton
Raglan
Lyndoch
Griffith
Brougham
Pakenham
Guilford
Harburn
Carlow
Herschel
Monteagle
Brightside
Darling
Denbigh
Matawatchan
North Canonto
Harcourt
Dudley
Dysart
Wilberforce
Haliburton
Mayo
Ashby
Miller
South Canonto
Lavant
Lanark
45°
BANCROFT
Dungannon
Cardiff
Faraday
Abinger
Dalhousie
Monmouth
Glamorgan
Limerick
Cashel
Effingham
Palmerston
Bathurst
Snowdon
Coe Hill
Wollaston
Bar
Clarendon
Anstruther
Chandos
Grimsthorpe
Anglesea
Big Gull Lake
Sharbot Lake
Kinmount
Cavendish
Sherbrooke
Galway
Tudor
Kennebec
Burleigh
Methuen
Lake
Kaladar
N. Crosby
Westport
Nephton
Harvey
Hinchinbrooke
Bedford
Bobcaygeon
Belmont
Sheffield
Sturgeon
Smith
Dummer
Marmora
Tweed
Loughborough
Ennismore
Lakefield
Havelock
Hungerford
Portland
Douro
Huntingdon
Camden East
Emily
Asphodel
Seymour
Rawdon
PETERBOROUGH
78
Campbellford
Tyendinaga
77
Kingston
Storrington
LENNOX AND ADDINGTON
HASTINGS
FRONTENAC

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

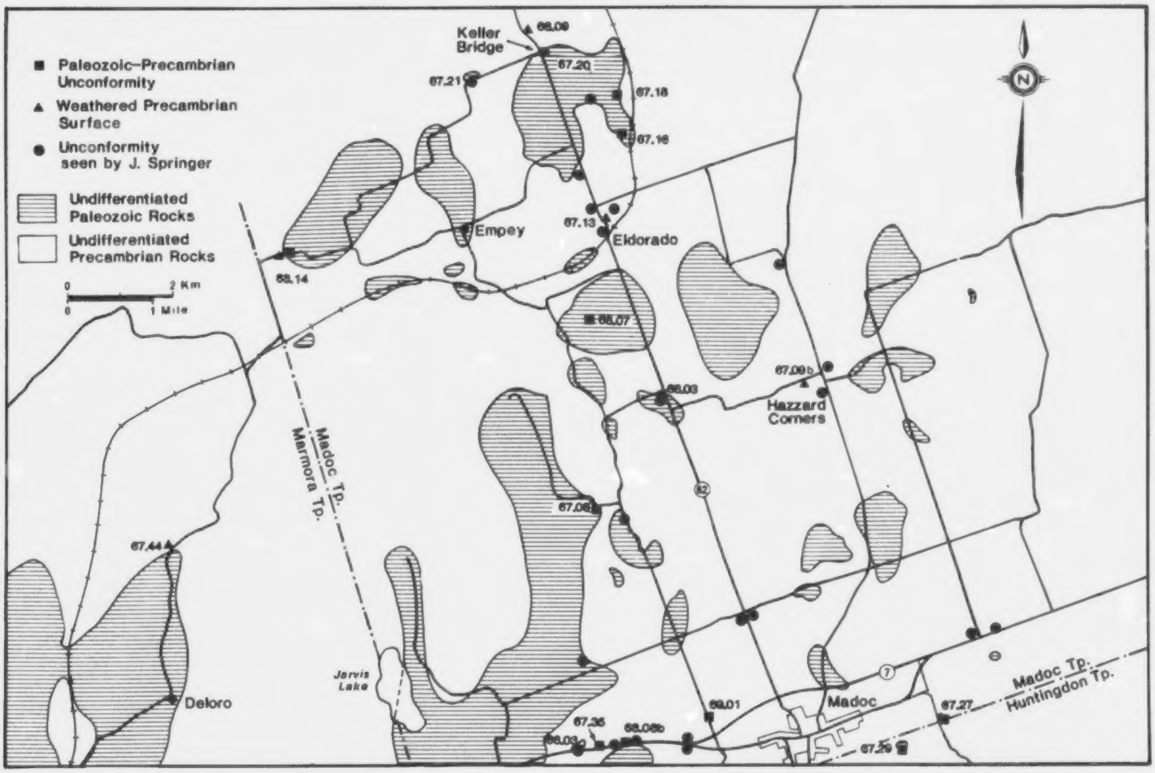

■ Paleozoic–Precambrian Unconformity
▲ Weathered Precambrian Surface
● Unconformity seen by J. Springer
▤ Undifferentiated Paleozoic Rocks
☐ Undifferentiated Precambrian Rocks
0
2 Km
0
1 Mile
N
Keller Bridge
68.09
67.20
67.21
67.18
67.16
Empey
67.13
Eldorado
68.14
68.07
67.09b
68.03
Hazzard Corners
Madoc Tp.
Marmora Tp.
62
67.06
67.44
Deloro
Jarvis Lake
7
Madoc
68.01
67.35
68.06b
66.03
67.27
67.29
Madoc Tp.
Huntingdon Tp.

Figure 069.1. Distribution of the Precambrian Paleozoic unconformity in the study area, and location of exposures examined.

arkosic, reddish, greenish, greyish, brown sandstones and, occasionally, dark, reddish conglomerate.

The basal Paleozoic sediments were deposited on Precambrian granites, metavolcanics, marbles, and schists. The nature and importance of the weathered zone on the Precambrian surface beneath these deposits change significantly from one lithological type to another, varying from superficial and weak on the metavolcanic surfaces to strong and extending a few metres into crystalline limestones (Figure 069.2). This variation is important in considerations of the unconformity surface acting as a conduit for fluids.

As well, the composition of the basal Paleozoic deposits is also related to the lithology of the Precambrian rock below them. Coarse conglomerates, containing large (up to 1.5m), angular fragments of metavolcanics, are common above the competent metavolcanics in paleogeographic depressions (Figure 069.2a). The basal Paleozoic deposits above granite have a granitic "disintegration zone", with blades of granite beneath arkosic sandstone (Figure 069.2b). Above Precambrian crystalline limestone, only relatively small, blunt fragments of marble, sometimes completely oxidized, are found in the earliest Paleozoic microconglomerates (Figures 069.2c, d).

During the field program, outcrops of Paleozoic rocks in contact with the Precambrian surface were mapped where possible, as well as some Precambrian outcrops resembling a weathered paleosurface. All of these exposures are located on Figure 069.1. Maps and reports by Hewitt (1968) and Carson (1980, 1981) were used in this part of the study.

CONCLUSIONS—UNCONFORMITY SURFACES

Mapping of the exposures of the Paleozoic-Precambrian unconformity in the Madoc area has shown that:

1. The basal Paleozoic series is "a composite which reflects both deposition at different times and widely varying environments of deposition within the same time intervals" (Springer 1985, p.254).
2. The Precambrian paleogeography controls the first Paleozoic deposits. This can be seen at exposures 66.03, 67.06 and 67.29 (Figure 069.1), and in the Marmoraton open-pit iron mine.
3. The development of weathered zones in the Precambrian paleosurface and the formation of paleokarsts are controlled by the composition of the Precambrian rocks (Figure 069.2). In the study area, only the marble shows significant weathered zones and real karst joints (outcrops 67.22 and 67.29, Figure 069.2d).
4. A relationship between a supergene enrichment of iron oxide and the Precambrian surface is evident. These supergene enrichments are ec-

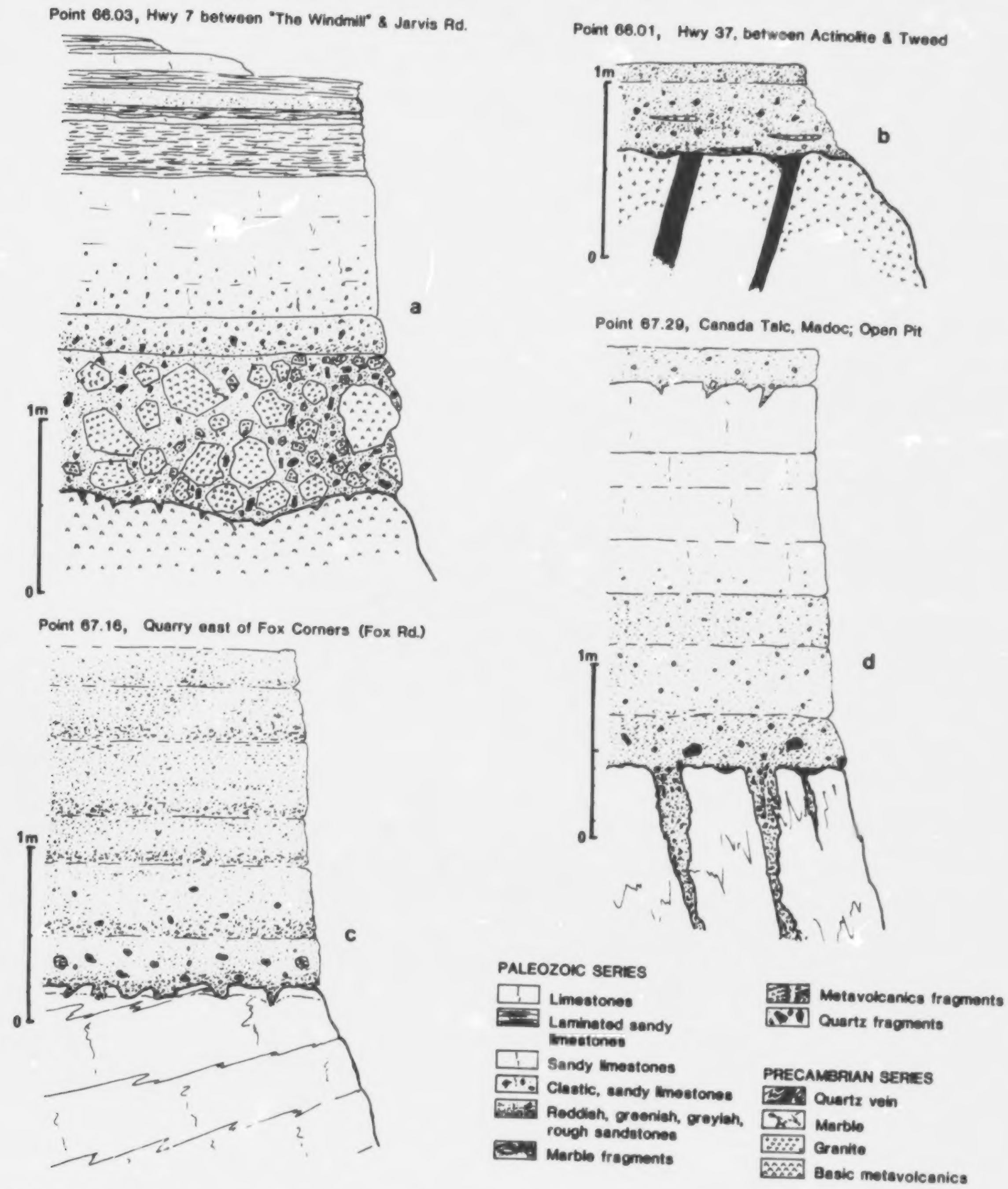

Point 66.03, Hwy 7 between "The Windmill" & Jarvis Rd.
1m
0
a
Point 66.01, Hwy 37, between Actinolite & Tweed
1m
0
b
Point 67.29, Canada Talc, Madoc; Open Pit
1m
0
d
Point 67.16, Quarry east of Fox Corners (Fox Rd.)
1m
0
c
PALEOZOIC SERIES
Limestones
Laminated sandy limestones
Sandy limestones
Clastic, sandy limestones
Reddish, greenish, greyish, rough sandstones
Marble fragments
Metavolcanics fragments
Quartz fragments
PRECAMBRIAN SERIES
Quartz vein
Marble
Granite
Basic metavolcanics

Figure 069.2. *Sketches of unconformity surfaces, illustrating differences in Precambrian weathering surfaces and basal Paleozoic sediments above Precambrian lithologies.*

onomically interesting insofar as they contain gold and iron deposits (Bannockburn gold and iron deposits, Richardson Gold Mine, Wallbridge Iron Mine, Cook Mine). However, in most cases, the oxidized zone is not sufficiently large to be exploitable.

5. Throughout the area, the basal Paleozoic lithology is a sandstone which fills the Precambrian paleokarst, sometimes accompanied by calcite and sulphide minerals (principally at outcrop 67.29, Figure 069.2d). Metals derived from Precambrian rocks could be trapped in this basal sandstone.

MINERALIZATION

Mineralization in the area occurs in the Precambrian as well as in the Paleozoic rocks; in veins and in massive or disseminated lenses close to or in contact with the unconformity surface. Several fluorspar, iron, and sulphide mineral occurrences were examined to determine their relationship with the unconformity. The characteristics of selected occurrences are summarized in Table 069.1.

CALCITE, FLUORITE, BARITE, CELESTITE, SULPHIDE MINERAL VEINS

This type of mineralization occurs in nearly vertical faults, trending generally 130° to 140°, that cut both Precambrian and Paleozoic rocks. The two most common mineralogical associations are carbonate+fluorite+sulphate and carbonate+sulphide; these can be found together as well as separately. Coarse grained, white to pinkish calcite is the most abundant mineral in the veins, which also contain variable amounts of fluorite, barite, celestite, and sulphides. The mineralization occupies lenticular fault cavities, apparently caused by horizontal displacement of the walls (Guillet 1964). These veins are characterized by:

1. Banding, especially of fluorite, calcite, and barite. "Oxide skin" (thin oxide coatings) occurs between bands.
2. Textures typical of open-space filling.
3. A general lack of visible wall rock alteration, suggesting a low temperature of formation. This is confirmed by fluid inclusion studies of fluorite (McCartney, *in* Carter 1984), which indicate a minimum filling temperature of about 125°C.
4. Minor presence of iron-copper sulphides and traces in several mines (Bailey, Lee Senior, Noyes, Rogers, Wallbridge Fluorspar) of a dark hydrocarbon substance.

These characteristics and "the geological setting and location..."[of the veins]"...near an intracratonic basin margin, resemble the Mississippi Valley type of deposits" (Carter 1984). This is also confirmed by the presence of real carbonate-sulphide mineral paleokarst deposits (Canada Talc, open pit, Madoc, locality 67.29).

IRON DEPOSITS

Small iron deposits are scattered throughout the study area. They occur in massive or disseminated lenses. The most important mineralization is hematite and magnetite. Siderite and sulphides of iron and copper (pyrite, chalcopyrite, bornite) are also present. The host rock of this mineralization is principally the crystalline limestone (the Precambrian marble of Hastings type).

The Canadian Sulphur Ore Company's massive pyrite deposit seems to be linked to a Precambrian acid volcanic centre (Hewitt 1968), but all of the other iron deposits, as seen by the author, seem to be skarn mineralizations linked to granitic bodies.

All of these occurrences have developed a gossan before the Paleozoic sedimentation occurred. In the Wallbridge Iron Mine (locality 68.03), evidence of this pre-Paleozoic event is visible. The gossan is trapped between the Precambrian surface and the earliest Paleozoic sediments. The basal Paleozoic conglomerate and sandstones contain oxidized fragments of the Precambrian surface.

The old land surface was subjected to hot, arid climatic conditions. According to Springer (1985): "The occurrence of indurated terra rosa deposits of strongly oxidized iron ores, and of coarse free gold then become self-evident as the results of subaerial weathering on an old land surface, upon which there has been supergene enrichment". Radioactive minerals (uraninite) found at locality 67.44, just beneath the unconformity surface, could also be an indication of a supergene enrichment in the Precambrian weathering zone.

Metals liberated from this old land surface could be trapped in basal Paleozoic series.

ECONOMIC POTENTIAL AND EXPLORATION GUIDELINES

The potential of finding significant quantities of fluorite in the area surrounding Moira Lake is high. On the northern side of Moira Lake, diamond drilling has indicated reserves of fluorite between the Bailey and Kilpatrick Mines. Important quantities of fluorite still remain in the Rogers Mine. On the south side of Moira Lake, the Johnston Deposit is indicated to extend about 100 m southeast (Guillet 1964). With modern mining techniques, the veins of this zone, therefore, remain as potential sources of fluorite if market conditions improve.

Soft hematite ore, used for natural iron oxide pigments (Koxholt 1985), could be viable as small operations from the gossans of Precambrian rocks.

The tectonic pattern of this area is more difficult than it seems. The veins of fluorite-barite-calcite and galena+calcite are related to this complex pattern. A detailed tectonic exploration of this area, particularly near fault junctions (Williams 1982, and personal communication 1986), could lead to new discoveries of these ores.

Arid climatic conditions in a lagoonal environment (of the Sabkha type) characterize the earliest Paleozoic deposits. Metals (Au, Ag, U, Pb, Zn, Cu, Fe) from the old Precambrian land are trapped in the detrital sediments. In the Wallbridge Iron Mine, basal sandstones are cemented by hematite. In other places, copper minerals are found in basal Paleozoic sandstones. Thus, the basal Paleozoic series represents a good "metal trap".

Geochemistry of these rocks could reveal interesting concentrations of metals or geochemical anomalies in relation with hidden Precambrian deposits, especially above Hastings-type crystalline limestones.

SUMMARY

Veins of fluorite-barite-calcite and calcite-sulphides, judging by their characteristics, seem to belong to the family of Mississippi Valley type ore deposits. Fluorite still exists in large quantities in some abandoned mines, and diamond drilling produced evi-

TABLE 069.1: CHARACTERISTICS OF SELECTED MINERALIZATION IN THE STUDY AREA.

No.	County	Township	Con.	Lot	Latitude	Longitude	Name	Commodities	History
67.46	Hastings	Huntingdon	14	10	44°29′13″	72°28′51″	Rogers	Fluorite, barite, calcite, celestite, minor sulphides. Vein in marble and Paleozoic sandstone.	Mine, shafts, abandoned. IMR 12, GR 73, Map 2159, Map P.2611.
68.04	Hastings	Huntingdon	12	10	44°28′23″	77°28′30″	Blakely	Fluorite, barite, calcite, celestite, sulphide: sphalerite. Vein in basal Paleozoic series.	Mine, shafts abandoned. IMR 12, GR 73, Map 2154, Map P.2611.
68.11	Hastings	Madoc	6	A	44°40′08″	73°32′45″	Hollandia	Galena, calcite. Minor sphalerite (Ag), pyrite, chalcopyrite, bornite, hematite. Vein in schist.	Mine, shafts, open cut, abandoned. GR 73, Map 2154, OFR 5515, Map P.2611.
67.29	Hastings	Huntingdon	14	14	44°30′10″	77°27′13″	Canadian Talc Limited, Madoc	Calcite, pyrite, chalcopyrite, barite, azurite, malachite, minor sphalerite. Vein in marble.	Vein also fills basal Paleozoic sandstone (paleokarst).
67.44	Hastings	Marmora			44°32′10″	77°37′27″	Deloro Road Pit	(1) Sulphides (Ag, Cu, Zn), hematite, calcite, quartz. Vein in marble, close to Deloro granite and basal Paleozoic sandstone. (2) Uraninite. Disseminated in marble, below the weathered zone of the marble.	Prospect.
67.36	Hastings	Madoc	10	9, N1/2	44°33′50″	77°25′19″	Canadian Sulphur Ore company (Wellington)	Pyrite, pyrrhotite, chalcopyrite, calcite, quartz. Massive lenses between schist and quartzite.	Mine, shafts, open pits, abandoned. GR 73, Map 2154, OFR 5515, Map P. 2611.
68.03	Hastings	Madoc	5	12	44°33′47″	77°30′32″	Wallbridge iron mine	Hematite (magnetite), limonite. Minor sulphide. Mineralization disseminated in Precambrian marble and Paleozoic sandstone.	Mine, open cut, abandoned. Gr 73, Map 2154, Map P.2611.

dence of continuities of this mineralization around abandoned mines. Tectonic studies could be helpful in finding unknown ore deposits, particularly in the proximity of fault junctions. This kind of mineralization does not seem to be directly related to the unconformity surface, with the exception of paleokarst fillings accompanied by a calcite-sulphide mineralization. In this last case, percolation of brines in cracks and fractures, directly from the Precambrian land surface, is syngenetic with the first Paleozoic sediments which fill the Precambrian karst.

Acid volcanism and skarns linked to plutonic intrusions produced hematite, magnetite, and other iron plus copper ore deposits. These minerals are found in disseminated or massive lenses, principally in the Hastings-type Precambrian marble. Paleoclimatic and paleogeographic conditions are responsible for strongly oxidized zones and supergene enrichments upon the Precambrian surface. During the Paleozoic transgression, the old Precambrian surface was disintegrated. Lagoons settled upon the old shield and brines were saturated in metals which were derived from Precambrian rocks. Some of these brines fill the Precambrian karst, and in other cases the basal detritic sediments trap the metals contained in the saturated brines.

The geochemistry of the basal Paleozoic sandstone could reveal hidden occurrences of supergene enrichment zones between the Precambrian surface and the basal series of the Paleozoic, and/or hidden occurrences in the Precambrian rocks.

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070. The Precambrian-Paleozoic Unconformity and Mineralization in the Madoc-Bannockburn Area, Eastern Ontario

Peter L. Churcher

Geological Consultant, Waterloo.

This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

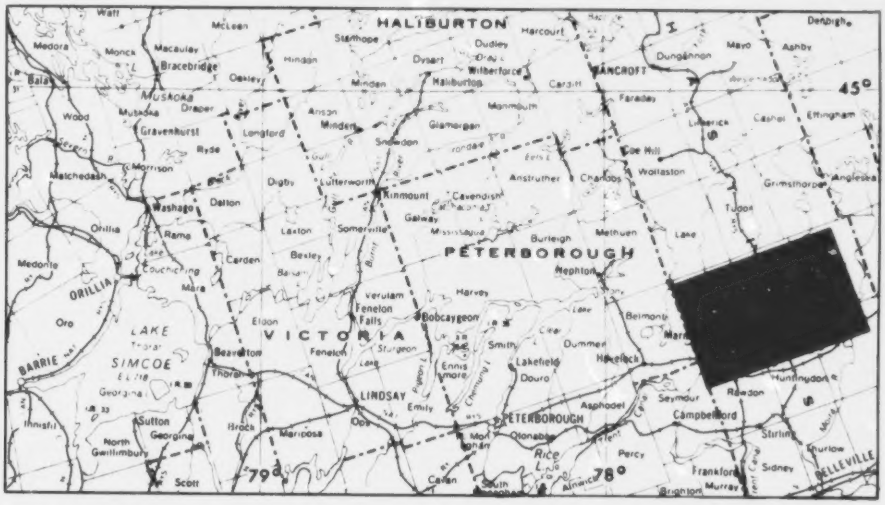
A preliminary investigation was undertaken to study possible roles which the Precambrian-Paleozoic unconformity surface may have played in the localization of various industrial mineral, sulphide mineral, and precious metal occurrences in the Tweed area, Eastern Ontario. Special attention was given to the relationship of the unconformity to the calcite-galena, and fluorite-barite-calcite veins in the area. All known occurrences of such vein mineralization are stratigraphically located just above or below the unconformity.

The unconformity surface represents a major hiatus extending from the late Precambrian to the early Middle Ordovician (Lumbers 1969), during which time deep erosion and karst development may have occurred (Springer 1985). The unconformity surface is overlain by a thin veneer of Shadow Lake Formation sandstone, which is locally conglomeratic and ferruginous.

Stratigraphic evidence clearly shows that deep weathering of local Precambrian iron skarns did occur during the hiatus, which resulted in the development of supergene enrichments of iron, copper, and gold (Springer 1985). This can be readily seen at the Wallbridge Hematite Mine, and at the Canada Talc Quarry in Madoc. The presence of Shadow Lake Formation sandstone infilling cracks and solution pits in the Grenville marbles also attests to weathering prior to the Ordovician marine transgression. Whether or not sufficient weathering occurred to enhance permeability in these rocks, thus providing the necessary pathways for the migration of later mineralizing fluids, is, however, uncertain. Similarly, whether additional permeable pathways were provided by the overlying Paleozoic sandstones, or were primarily due to fracture permeability is unknown. These were basic questions posed during the course of the study.

HISTORY AND GENERAL GEOLOGY OF THE VEIN OCCURRENCES

The Precambrian-Paleozoic unconformity separates Grenville age plutonic, metavolcanic, and metasedimentary rocks from the Middle Ordovician sandstone, siltstones, and limestones of the Shadow Lake Formation. This contact surface is cut by numerous post-Ordovician veins in the study area, as well as in other parts of southern Ontario, western Quebec, and New York State. Figure 070.1 shows the location of the study area with respect to regional structure, and the location of other similar vein occurrences. Figure 070.2 shows the location of several fluorite-barite-calcite veins of the Madoc area, in the southern half of the study area.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

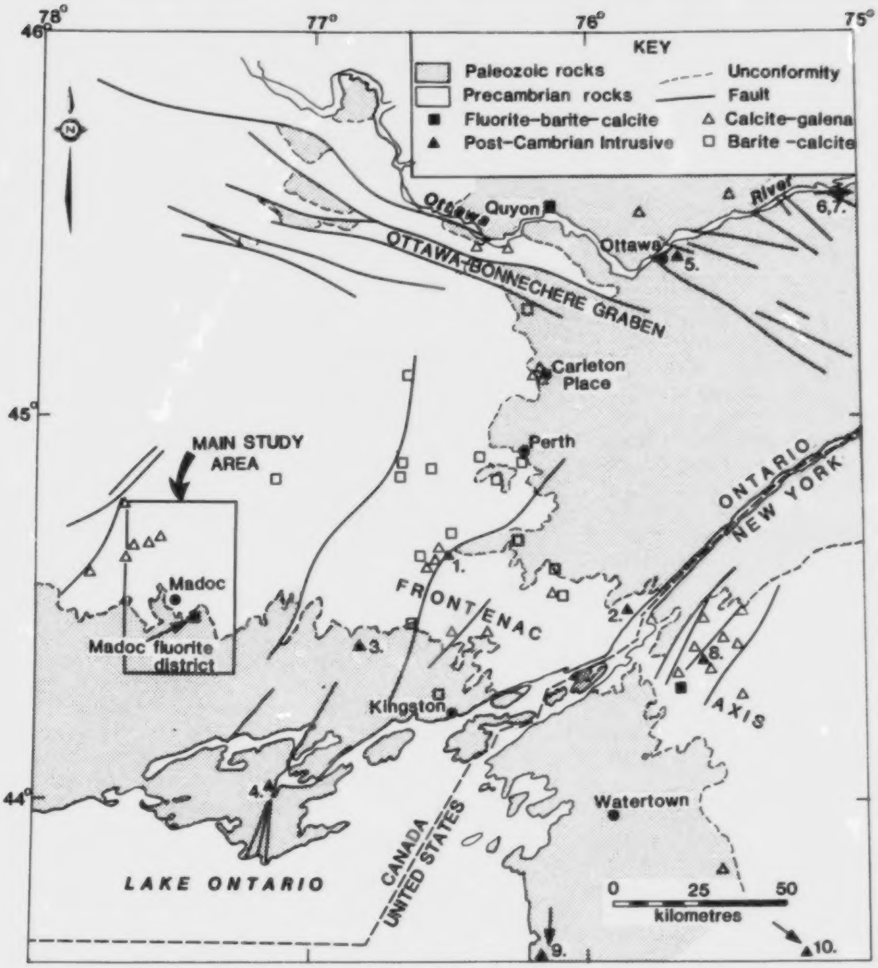

78°
77°
76°
75°
46°
45°
44°
KEY
Paleozoic rocks
Precambrian rocks
Fluorite–barite–calcite
Post-Cambrian Intrusive
Unconformity
Fault
Calcite–galena
Barite –calcite
Ottawa River
Quyon
Ottawa
5.
6,7.
OTTAWA-BONNECHERE GRABEN
Carleton Place
Perth
MAIN STUDY AREA
Madoc
Madoc fluorite district
FRONTENAC AXIS
ONTARIO NEW YORK
1.
2.
3.
4.
8.
9.
10.
Kingston
Watertown
CANADA UNITED STATES
LAKE ONTARIO
0 25 50
kilometres

Figure 070.1. *Map showing relationship of veins to known structure, intrusions and the Precambrian-Paleozoic contact (after Buddington 1934, Guillet 1963, Brown 1983, and Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Tweed).*

The vein occurrences can be grouped into three classes, based on the principal ore minerals (Sangster 1970). These three types are fluorite-barite-calcite, calcite-galena, and barite-calcite. Only the first two vein types are considered in this report.

These two vein types are believed to be genetically related, having similar characteristics throughout the area shown in Figure 070.1. The mineralization always occurs in *en echelon* fracture systems trending roughly northwest. The veins exhibit a characteristic pinch and swell structure, forming pods of crustiform-type ore (Uglow 1916; Guillet 1963, 1964). They are hosted in a number of different lithologies, including granite, andesite, metavolcanics, metasediments, and limestones (Guillet 1964).

The wall rock is frequently brecciated, with "horses" of country rock incorporated in the ore. Hydrocarbons are frequently found in the veins in the form of tar. Occasionally the tar is found trapped in the ore minerals as inclusions.

Two hypotheses have been proposed for the origin of these veins. Differences in these are the fluid source, and the mechanism by which the host rock fractures were formed.

The first hypothesis, first suggested by Uglow (1916), and later refined by Wilson (1929), Sangster (1970), and Brown (1983), proposes a meteoric origin for the mineralizing fluids. Meteoric waters percolating down through the Paleozoic cover scavenged the necessary F, Ba, Sr, and Ca to form fluorite, barite, celestite, and calcite respectively. These minerals precipitated when open fractures were reached near the unconformity, in a similar fashion to that of Mississippi Valley-type deposits (Brown 1983). Likewise, Ca and Pb-Zn were leached from the exposed Precambrian marbles and were also precipitated in open fractures close to the unconformity.

The second hypothesis, that of a magmatic fluid source, was also proposed by Uglow (1916) as a possible explanation for the occurrence of the veins, but was rejected due to apparent lack of intrusions in the area. This is now known not to be true. The model proposes that the source of the mineralizing fluids was late stage magmatic waters, coming from deep seated intrusions, and migrating along fractures

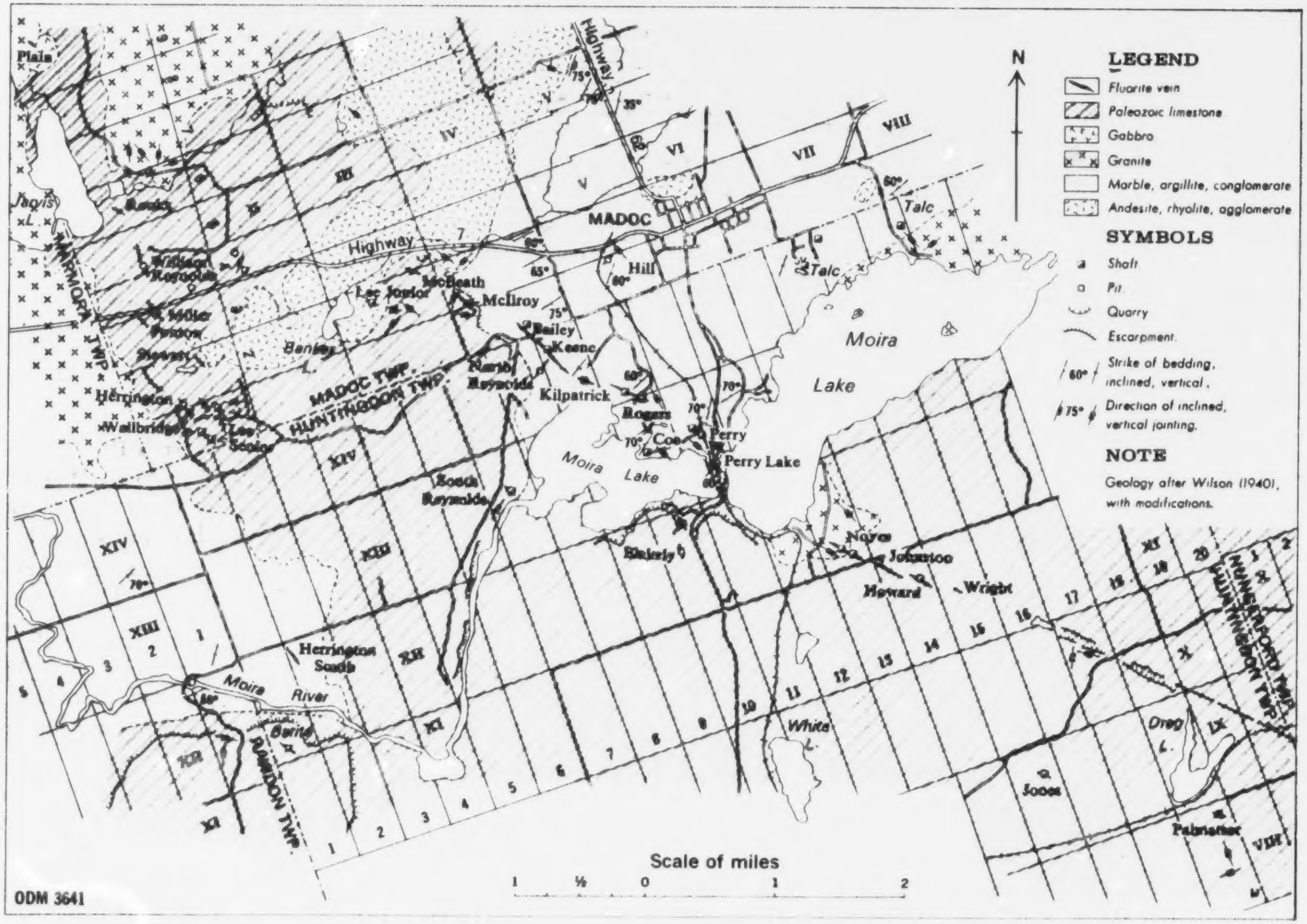

LEGEND
Fluorite vein
Paleozoic limestone
Gabbro
Granite
Marble, argillite, conglomerate
Andesite, rhyolite, agglomerate
SYMBOLS
Shaft
Pit
Quarry
Escarpment
Strike of bedding, inclined, vertical.
Direction of inclined, vertical jointing.
NOTE
Geology after Wilson (1940), with modifications.
N
MADOC
Highway 7
Moira Lake
Perry Lake
Moira River
White L.
Drag L.
Jarvis L.
MADOC TWP.
HUNTINGDON TWP.
MARMORA TWP.
RAWDON TWP.
HUNGERFORD TWP.
Plain
Hill
Talc
McIlroy
Bailey
Keene
Kilpatrick
Rogers
Coe
Perry
Blakely
Noyes
Johnston
Howard
Wright
Jones
Palmatier
Herrington
Wallbridge
Herrington South
Baird
North Reynolds
South Reynolds
Stewart
Benley
Scale of miles
1 ½ 0 1 2
ODM 3641

Figure 070.2. Fluorite occurrences in the Madoc area (from Guillet 1964).

to the unconformity surface, where they precipitated to form the observed mineralization. The author supports this hypothesis for the reasons outlined below.

There are also two models pertaining to the development of the fractures which host the veins. The first, proposed by Brown (1983), suggests the *en echelon* veins are infilled tension fractures associated with horizontal movement along northeast-trending regional faults (*see* Figure 070.1). The second hypothesis proposes that the northwest-southeast-trending fractures are genetically related to those of the Ottawa-Bonnechere graben system to the north (*see* Figure 070.1). Both hypotheses are structurally feasible.

FIELD WORK

The field investigation was divided into three parts. The first part involved the study of the unconformity outcrops outlined in Springer (1985). In addition, the unconformity contact and overlying strata were examined at outcrop locations near the junction of Highways 37 and 7, at the Marmoraton Mine at Burleigh Falls, and at the Canada Talc Mine in Madoc. The outcrops were examined to determine the lithology above and below the contact surface and the physical nature of the contact surface, and to check for features related to karsting.

Throughout the study area, the Shadow Lake Formation sandstones rest unconformably on Grenville marbles, metasediments, and granitic plutons. The contact surface is generally flat on a local scale, but shows marked topographic relief on an area-wide scale.

Very little physical evidence of karsting and cave development was noted in the marble outcrops visited, with one exception. The east quarry at the Canada Talc Mine in Madoc has excellent exposures of solution channels and cave development in the Precambrian marbles. Some of these caves are infilled by Paleozoic sandstone, indicating their existence prior to the sandstone deposition. Others are lined with large crystals of dogtooth calcite and disseminated sulphides. This rock has been the locus of intense hydrothermal alteration, which may have

TABLE 070.1: POST-ORDOVICIAN ALKALIC INTRUSIVE ROCKS IN EASTERN ONTARIO, WESTERN QUEBEC, AND NEW YORK STATE. ALL AGES DETERMINED BY K/Ar, EXCEPT WHERE NOTED.

Name*	Type	Age (my)	Orientation	Reference
1. Wolfe Lake, Ontario	diabase dike	336 ± 23** 337 ± 23**	NW-SE, 90° dip	Hon (1970)
2. Mallorytown Landing, Ont.	syendiorite dike	407 ± 23 411 ± 23	NE-SW, 90° dip	Hon (1970)
3. Varty Lake, Ontario	ultramafic dike (kimberlite?)	166 ± 9 167 ± 9 169 - 170	120°, 90° dip	Hon (1970) Barnett et al. (1984)
4. Picton, Ont.	ultramafic dike (kimberlite?)	191 - 197	105°, 77°S dip	Barnett et al. (1984)
5. Blackburn Hamlet, Ont.	carbonatite dike	190 ± 10	090°, 90° dip	Hon (1970)
6. Chatham-Grenville, Que	syenite stock	450		Doig and Barton (1968)
7. Rigaud Mountain, Que.	syenite stock	451		Doig and Barton (1968)
8. Pierces Corner, N.Y.	diabase dike	405 ± 11 440 ± 10	NE-SW	Brown (1975)
9. Portlant Point, N.Y.	kimberlite dike	136 ± 8 (Rb/Sr)*** 430 ± 23		Zartman et al. (1967)
10. Manheim, N.Y.	kimberlite dike	307 ± 15**** 130 ± 10 (Rb/Sr)		Zartman et al. (1967)

*For locations see Figure 070.1. Numbers beside name correspond to location number.
**This date may be young due to contamination. Hon (1970) suggests an age of 400-420 my.
***Hosted in Middle Ordovician, therefore contaminated. Rb/Sr date more valid.
****Hosted in the Lower Devonian, therefore contaminated. Rb/Sr date more valid.

been instrumental in the development of the caves, since similar features have not been found elsewhere in the study area.

The second phase of the field investigation involved the study of three post-Ordovician igneous intrusions in southern Ontario. The three intrusions visited were the Varty Lake and Picton ultramafic (kimberlitic?) dikes, and the Blackburn Hamlet carbonatite dike. All three dikes were emplaced into the Middle Ordovician Trenton-Black River Group, in which many of the veins are hosted. The locations of these dikes, and others in the area, are shown in Figure 070.1. All known post-Ordovician igneous intrusions in the region are listed in Table 070.1.

The purpose of this part of the study was to delineate any wall rock alteration associated with the dikes which might be related to the vein mineralization. In the past, the lack of igneous intrusions in southern Ontario and in New York State was cited as evidence for rejecting the magmatic origin of the veins.

An examination of the Blackburn Hamlet and Picton dikes revealed the presence of wall rock alteration/brecciation associated with the emplacement of the dikes. A breccia similar to that found in the veins was noted in the limestones near the dikes. The mineralization in the breccia of the Blackburn Hamlet dike is predominantly ferroan dolomite, whereas at the Picton dike it is composed of white to pink, coarse, translucent calcite with trace amounts of barite. Unfortunately, the Varty Lake dike is not exposed sufficiently to define similar wall rock alteration patterns, but the dike-limestone contact indicates that the wall rock is extensively brecciated and altered to ferroan dolomite and/or serpentine.

The third and largest phase of the study involved the investigation of the vein occurrences throughout the region. In total, 32 barite-, fluorite-, and galena-bearing vein occurrences were visited. Notes were made, where possible, of vein orientation, mineralization, and vein-wall rock association, and samples were collected for thin section and geochemical work.

Many of the sites were mined or excavated over 80 years ago and have not been worked since, hence they are in general overgrown, filled in, or water-filled, making the study of the veins themselves difficult. Good samples were obtained from the dumps in the majority of cases. These were supplemented with accounts from the literature and by observation of mineral specimens held in private and public collections.

SUMMARY

Stratigraphic evidence exists that suggests there was deep weathering and supergene enrichment of iron, copper, and gold associated with the hiatus during the time of the Precambrian-Paleozoic unconformity.

Evidence is also present that shows that dissolution of the marbles did occur, but very little evidence exists that points to regional karst development which is suitably mature enough to have enhanced the permeability in these rocks. The overlying sandstones, as well, do not appear to have contributed much to the regional permeability, due to early stage calcite cementation. Without a high regional permeability, mineralizing fluids could not have migrated through these rocks. Therefore, the majority of the permeability in these strata was probably provided by the fractures which host the veins themselves. The fact that these veins and fractures remain major conduits for fluids even today supports this interpretation.

Further work regarding the origin of these veins is warranted. This should be in the form of geochemical studies, aimed at defining the temperature of formation, and a chemical association between the observed wall rock alteration associated with dike emplacement, and the vein gangue mineralization.

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071. Structural Setting of the Fluorite Vein Deposits of the Madoc Area, Southern Ontario

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

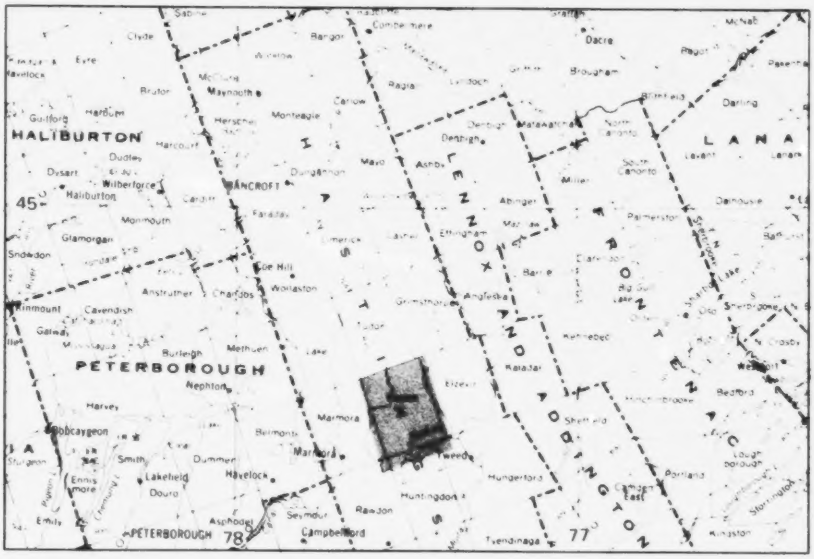
Both deformed Precambrian metamorphic and igneous rocks, and gently dipping Paleozoic sedimentary rocks, are exposed extensively in the Madoc area. At the time of Paleozoic marine transgression, the Precambrian surface was characterized by the development of laterite and karst (Springer 1985, p.255). The area has been mapped by Wilson (1940a,b), Winder *et al.* (1975), Liberty (1963), Hewitt (1968), Carson (1980, 1981a), and Bartlett and Moore (1983). Quarries in the Paleozoic rocks have been described by Goudge (1938), Hewitt (1964), Carson (1981b), and Verschuren *et al.* (1986).

Fluorite-bearing veins (Wilson 1929; Rupert 1963; Guillet 1964; Hewitt 1968; Melanson and Robinson 1982) occur in a zone approximately 15 km long and 5 km wide, trending southeasterly through the southwestern part of Moira Lake. The veins strike southeasterly, and have been subdivided into the Moira Lake group (to the southeast) and the Lee-Miller group (to the northwest). Mining was conducted from 1905 to 1961. Veins are present above and below the Precambrian-Paleozoic unconformity, and localization of the veins has been influenced by normal faults. The distribution of the faults has been poorly known, resulting in an inadequate understanding of the structural and stratigraphic setting of the veins. Geological field work during the Summer of 1986, therefore, involved examination of Paleozoic outcrops and locating of Precambrian outcrops, in order to detect vertical displacement and to determine the location of faults. The abandoned open-pit iron mine of Marmoraton Mining Company at Marmora provided a reference section, since all except the uppermost part of the Paleozoic sequence present in the Madoc area is exposed in it. The field examination involved parts of Madoc, Marmora, Rawdon, Huntingdon, and Hungerford Townships.

Geophysical work during the Summer of 1986 consisted of seismic refraction profiling at O'Hara's Mill in Madoc Township. It was a continuation of the 1984-85 program (Thompson 1986) which yielded fault responses at three other sites in Madoc, Huntingdon, and Hungerford Townships (Bailey Mine, Crookston Road, and Buller Siding).

MARMORA REFERENCE SECTION

The Marmora reference section consists of 49.60 m of Middle Ordovician terrigenous clastic and carbonate rocks which unconformably overlie Precambrian magnetite-bearing skarn. A subdivision of the section (in ascending order) is as follows: Unit 1 (6.27 m), red and green sandstone and siltstone; Unit 2 (6.60 m), red and green dolomitic limestone and dolostone; Unit 3 (13.24 m), limestone (including dolomitic limestone), dolostone, and sandstone; Unit



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

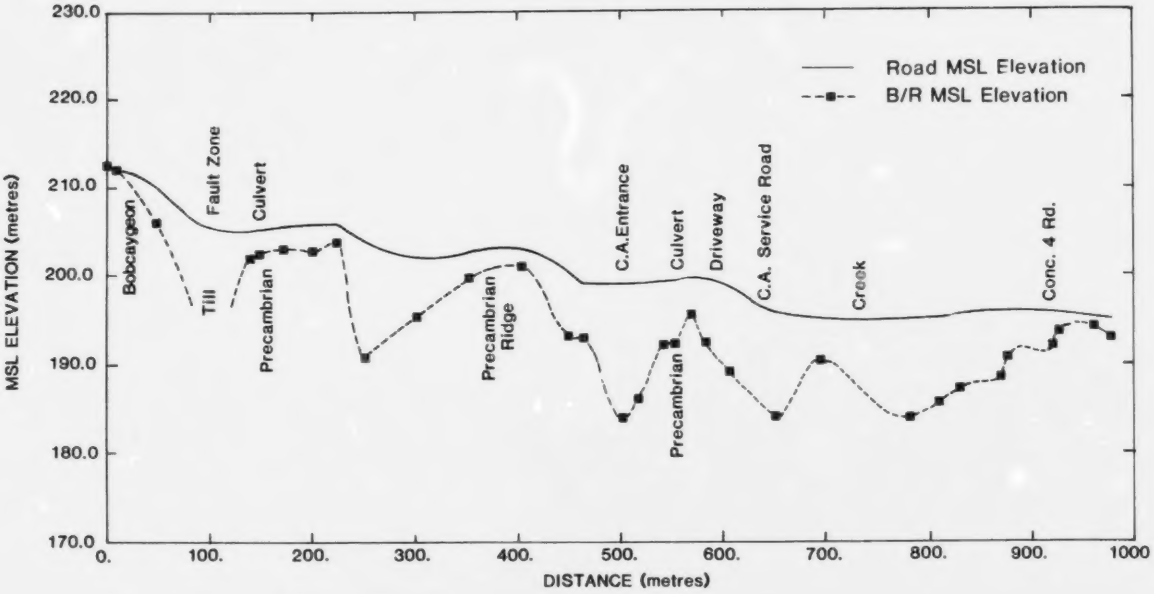


Figure 071.1 *Seismic survey results for the O'Hara Mill Site (squares indicate seismic depth points).*

4 (7.19 m), thinly to medium bedded lithographic to finely crystalline limestone; Unit 5 (13.70 m), thinly to massive bedded lithographic to finely medium crystalline limestone; and Unit 6 (2.60 m), thinly to massive bedded lithographic to medium crystalline limestone. Unit 1 is equivalent to Hewitt's (1960, p.46), Unit M1; Unit 2, to Unit M2 and the lower part of Unit M3; Unit 3, to the upper part of Unit M3 and all of Units M4 and M5; Unit 4, to Unit M6; Unit 5, to Unit M7 and the lower part of Unit M8; and Unit 6, to the upper part of Unit M8. Hewitt's (1960, p.46) thickness figure for Unit M1 is considerably less than that given here for Unit 1, since his measurement was made adjacent to a Precambrian topographic high.

Unit 1 is referred to here as the Shadow Lake Formation; Units 2 and 3, as the lower member (lower and upper submembers, respectively) of the Gull River Formation; Unit 4, as the upper member of the Gull River Formation; and Units 5 and 6, as the lower member (lower and upper submembers, respectively) of the Bobcaygeon Formation. There are discrepancies between this subdivision and those used by Liberty (1964, p.32-33), Winder and Sanford (1972, p.52), Winder *et al.* (1975, p.140-142), and Carson (1981b, p.52-56, 63-65). The base of the Gull River Formation was placed stratigraphically lower by Liberty (1964) and higher by the other authors, and the top of the Gull River Formation was placed stratigraphically higher by all of the above authors. Location of the Shadow Lake-Gull River contact in the subdivision used here is based on the absence of limestone (including dolomitic limestone) from the Shadow Lake Formation. Location of the Gull River-Bobcaygeon contact is based on the occurrence of relatively thinly bedded lower-purity limestone in the upper part of the Gull River Formation, and relatively thickly bedded higher-purity limestone in the lower part of the Bobcaygeon Formation, and is consistent with Liberty's (1967, p.50) placement of the Gull River-Bobcaygeon contact in the Ottawa Valley.

FAULT LOCATING BY SEISMICS

The seismic refraction method was used to identify and locate a major fault between the Lower Bobcaygeon limestone on the west and Precambrian rock on the east, in the vicinity of the O'Hara's Mill Conservation Area north of Madoc. The seismic survey line extended about 1 km across most of Concession 3 along the 5-6 side road in Madoc Township.

Seventeen forward and reverse refraction spreads, 52 m in length, gave a continuous line of depth measurements, and identified the subsurface material by seismic velocity. Three different types of seismographs were used in the course of this survey: a single-channel Geometrics ES-125; a 12-channel Geometrics ES-1210F (on loan from the Civil Research Department, Ontario Hydro); and a newly developed 12-channel Geometrics ES-1225.

Figure 071.1 shows a topographic profile of the 5-6 sideroad along the survey line and the seismic depth results. West of the survey line is a flat-lying Lower Bobcaygeon limestone plain. The limestone forms a small scarp about 6 m high on the road at the start of the survey line. To the east, the road is nearly level for the first 200 m of the survey line, then drops with a slight jog over another scarp about 4 m. The road is then built up about 2 m over a land depression (seismic spreads were done at land surface level). The land then rises gradually to road level over a Precambrian ridge. Further east, the road is again built up about 2 m above the land, which drops about 6 m to a creek draining O'Hara Mill Lake. The road continues more-or-less level across an overburden-filled valley to the east.

The bedrock profile of seismic depths in Figure 071.1 shows that a fault between the Lower Bobcaygeon limestone and the Precambrian basement exists just east of the limestone scarp at the start of the survey line. Evidence for the fault is a deep depression about 50 m wide, filled with till-like material where bedrock could not be detected. Also, near-surface Precambrian rock was detected on the east side of the depression, and the bedrock depths and velocities, indicate that the entire remainder of the seismic line to the east is underlain by Precambrian knolls and ridges.

This work has demonstrated the usefulness of the seismic method as an aid in fault mapping by confirming the existence of a fault and determining its precise location in an area of overburden. This is especially important in an area where faults are almost never exposed in outcrop.

Structural Setting of Veins

The structural geology of the fluorite-bearing veins has been described by Wilson (1929, p.46-47), Rupert (1963, p.6-10), Guillet (1964, p.21-23), and Hewitt (1968, p.17-18). The wallrock is commonly characterized by gently or steeply plunging slickensides at its contact with vein material, but evidence for significant fault displacement along fractures containing veins is generally lacking (and is not to be expected in most cases, in view of the common left-lateral *en echelon* occurrence of the veins). Significant vertical fault displacement probably occurred immediately northeast of the vein at the Bailey Mine (Thompson 1986, p.299); along the fracture containing the vein at Perry Mine, where Wilson (1929, p.47) noted offset of a contact between Precambrian marble and granite; and to the southwest of the Wright Mine (Thompson 1986, p.299-304), where Guillet (1964, p.23) noted a southeasterly trending depression.

The present program has resulted in the mapping of a large number of previously unsuspected normal faults in the Madoc area. Vertical displacements well in excess of the maximum thickness of Paleozoic rock present (approximately 55 m) have been detected. One of these faults was exposed in the Noyes Mine, where the faulted Precambrian-Paleozoic contact was mistakenly interpreted by Wilson (1929, p.46) as an unconformable contact, offset horizontally along the fracture containing the vein. The main reasons for the previous lack of recognition of these faults have been their lack of exposure, and the assumption that the irregular topography of the Precambrian surface is solely responsible for the observed geological relationships. The lack of exposure of faults has resulted from their susceptibility to weathering. The assumption of prominent Precambrian topographical highs has been invalidated by the seismic survey results, and is inconsistent with the common lack of occurrence of steep dips and coarse terrigenous clastic rocks in Paleozoic carbonates adjacent to their contact with Precambrian rock. Adjoining areas undoubtedly also contain a large number of normal faults: these include the Parks Creek "monocline" of Kay (1942, p.633-634), located 25 km southeast of Madoc.

Normal faults of the Madoc area strike parallel to the rift zones of the region (Ottawa Valley, Timiskaming Valley, Champlain Valley, and southern Great Lakes). As in the Ottawa Valley (Williams and Telford 1986, p.12), fault traces are normally gently curved, but may be distinctly curved in the vicinity of fault junctions. Fluorite-bearing veins are located adjacent to faults, and the deposits which have been of most economic significance are located close to fault junctions.

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072. Building Stone, Eastern Ontario

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

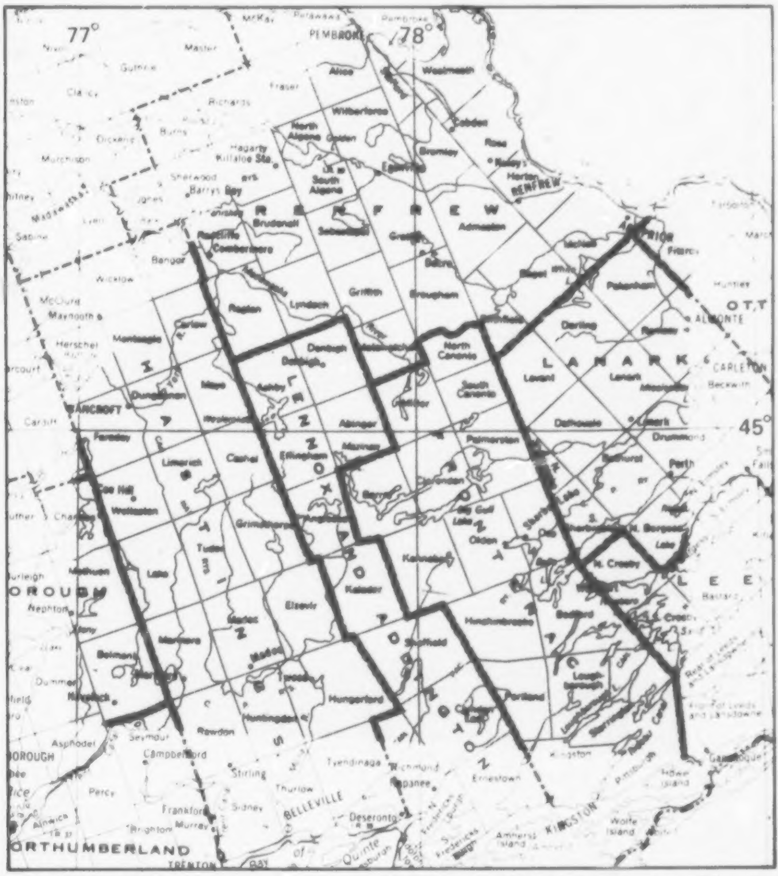
INTRODUCTION

Several government-sponsored geology projects to evaluate Ontario building stone resources have been initiated over the past three years. These programs, largely centred in northwestern, central, and southeastern Ontario, resulted in the publication of several recent building stone reports. These reports include: Les Consultants Sogir Incorporated (1984), Storey (1983, 1984, 1986), Kennedy *et al.* 1986), Vos *et al.* (1982), and Verschuren *et al.* (1985; 1986).

Due to the continued interest in building stone, and the perceived increased demand for stone products, this project was started to further evaluate and promote the building stone resources of eastern Ontario. This year's work represents the first phase of a three-year program.

The emphasis of this project is to identify and evaluate stone resources amenable to the production of architectural stone, primarily granite panels, for exterior and interior curtain wall construction and flooring. These end uses represent the largest, and fastest growing, potential markets in terms of both volume and value.

Since the required physical characteristics of a building stone deposit, producing granite panels, are similar to those required by a monumental stone producer, this project is equally directed at delineating sites suitable for monumental production. Other types of stone products, many of which are obtainable from the waste produced in extracting large quarry blocks for architectural and monumental stone applications, and which traditionally serve more local markets, are also being considered during the course



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles of this study. Marble and limestone are also being evaluated as potential building stone sources.

METHODOLOGY

Research of geological reports and maps was conducted to locate potentially favourable plutonic rocks. Emphasis was placed on delineating intrusive bodies which: a) are described as being late- or posttectonic in age; b) possess a massive to weakly foliated structure; c) are reasonably accessible (within 2 km of a road); d) are physically unaltered or not deeply weathered; and e) are not intensely jointed or fractured.

Air photograph interpretation was used to locate the largest outcrop exposures, to estimate the physical characteristics of the rocks (i.e. foliation, jointing, etc.), and to determine access.

Favourable sites are being assessed and sampled on a reconnaissance scale. Larger samples, in the order of 0.5 m^3, are being collected from approximately 35 sites this year for test cutting and polishing. Follow-up detailed analysis of the more promising areas is scheduled for subsequent years of the current project.

PROGRESS

To date, over 100 sites have been documented from approximately 40 plutonic bodies in eastern Ontario (Table 071.1). These bodies represent mafic to felsic compositions, possessing a wide spectrum of colours, grain sizes, and textures.

Three areas, identified during the 1985 field season (Verschuren *et al.* 1986), are currently being mapped in detail. These plutonic bodies include the Battersea Granite, the Lyndhurst Granite, and the La Rose Bay (Donaldson Bay) Diorite. Twelve properties have been sampled (0.5 m^3 samples) for test cutting and polishing, at the time of writing.

Described below are two plutonic bodies which were investigated during the 1986 field season and which show potential as building stone sources.

MOUNT MORIAH SYENITE

The Mount Moriah Syenite is located approximately 25 km north of the Village of Madoc in Madoc, Elzevir, Tudor, and Grimsthorpe Townships, Hastings County. The southern portion of the intrusion is accessible via the Lingham Lake road from the Hamlet of Cooper. A forest access road, which services a now-abandoned fire tower, traverses the intrusion from the south, but is currently in poor repair. The centre of the intrusion is defined by UTM co-ordinates 306500E and 4953500N on NTS Map 31 C/11. The Mount Moriah Syenite forms a local topographic high rising approximately 100 m above the surrounding terrain, which is primarily underlain by metavolcanics. Exposure, approximately 40 percent, is excellent. The intrusion is roughly circular in shape with an approximate diameter of 5 km, and has been described by Hewitt (1968), Lumbers (1969), and Brown and Thivierge (1979).

The dominant phase of the syenite is a fine- to medium-grained, equigranular rock, composed essentially of orthoclase and microcline with minor amounts of plagioclase and rare quartz. Mafic constituents include varying proportions of pyroxene, hornblende, and biotite, and comprise 10 to 20 percent of the rock. Minor accessory minerals include apatite, zircon, allanite, magnetite, epidote, and calcite.

The rock is massive, but locally possesses a weak igneous fabric. The intrusion is interpreted to be posttectonic in age.

A later phase of the Mount Moriah Syenite crops out as an arcuate mass in the southwestern part of the body (Brown and Thivierge 1979). This medium-grained rock, which is composed essentially of microcline with minor amounts of plagioclase, biotite, and quartz, is separated from the main mass of the intrusion by an arcuate band of metavolcanics. This later phase is primarily syenitic in composition but contains monzonite and granite phases.

The main mass of the Mount Moriah Syenite possesses a unique pinkish mauve colour. The colour and texture are uniform over large areas, and the rock is intruded by minor crosscutting dikes and limited quartz veins. Mineralogically, the rock is uniform and contains virtually no inclusions. Limited surficial alteration of exposed outcrops suggests satisfactory weathering characteristics. Only partial decomposition of the mafic constituents (augite and hornblende) is visually noted, to a depth of less than 1 cm.

Brown and Thivierge (1979) described a pervasive deuteric alteration (alteration during emplacement and consolidation of the intrusion) resulting in minor recrystallization and partial breakdown of some of the constituent minerals. This process results in partial unmixing of the K-feldspars, minor sericitic alteration of plagioclase, local recrystallization of quartz, and partial breakdown of augite to hornblende and subsequently to biotite. Local brittle deformation, which occurs preferentially proximal to major lineaments, is also noted by Brown and Thivierge (1979); it resulted in microfracturing of the feldspars.

Jointing is locally intense; however, areas of moderate and limited jointing are common. The major joint planes occur at 0.3 to 2.5 m spacings, averaging in the 1 m range. There are generally two or three vertical to subvertical major joint sets at any one location, accompanied by horizontal to subhorizontal sheeting. Prominent sheet joints are moderately spaced, ranging from 0.5 to 2.5 m apart, and averaging approximately 1.5 m. Major joint planes are generally regular in pattern and are straight and continuous for distances of up to 25 m. Joint surfaces are notably clean and free of any obvious alteration or surficial mineralization.

In addition to the major joint sets, minor, less well defined joints are visible in most outcrops. In contrast to the major joint sets, these joints are typically irregular in pattern, curved in attitude, and discontinuous. Weakly defined, closely spaced (1 to 10 cm), horizontal fracture planes are commonly observed in hand specimens. The vertical extent of these fractures is unknown but they may be a surficial exfoliation feature, restricted to the upper limits of the intrusion.

TABLE 072.1: PLUTONS OF EASTERN ONTARIO (McCrank *et al.* 1981) EXAMINED FOR BUILDING STONE POTENTIAL.

No.	Pluton Name	No of Sites	Colour
1	Abbotts Hill Intrusion	7	grey-pink
2	Addington Intrusion	2	pink
3	Bald and Tommy Lakes Intrusion	1	black
4	Bathurst Intrusion	1	pink
5	Beaver Creek Complex	6	grey-pink
6	Coe Hill Granite	5	buff-grey
7	Cordova Pluton	16	black-green
8	Crowe Lake Complex	1	brown
9	Deloro Pluton	13	brown-red
10	Elzevir Batholith	13	grey
11	Gawley Creek Syenite	5	pink-brown-green
12	Glanmire Complex	5	grey
13	Grimsthorpe Trondhjemite	2	grey
14	Jocko Lake Complex	1	grey-black
15	Lanark-Oso Mafic Intrusion	4	blue-black
16	Lavant Mafic Intrusion	3	grey
17	Leggat Lake Intrusion	7	pink
18	Lingham Lake Complex	1	grey-black
19	Lynhurst Granite	1	pink-red
20	Malone Pluton	1	pink
21	McLean Pluton	10	pink
22	Moira Lake Intrusion	1	pink
23	Mount Moriah Syenite	8	brown
24	Mountain Grove Mafic Intrusion	1	black
25	Newboro Pluton	1	red-brown
26	Northbrook Batholith	1	grey-brown
27	Northwest Limerick Intrusion	1	grey
28	Rideau Lake Complex	5	pink-red
29	Skootamatta Lake Granite	3	pink-black
30	Thanet Gabbro Complex	1	black
31	The Ridge Granite	1	red
32	Umfraville Gabbro	2	grey-black
33	Wadsworth Trondhjemite	1	pink
34	Weslemkoon Granite	2	grey
35	Westport Complex	2	pink-brown
36	White Lake Intrusion	3	pink
37	Wilkinson Anorthosite	1	dark grey
	Bellrock Anorthosite	3	grey-black
	First Depot Anorthosite	1	black
	Tamworth Anorthosite	1	dark grey
38	Wolfe Lake Complex	2	pink-brown
39	Wollaston Granite	4	pink
40	Wollaston Lake Gabbro	1	grey

Uniformity of colour and texture, along with local areas of moderate jointing, suggest that the Mount Moriah Syenite should be further investigated as a potential source of building stone.

McLEAN PLUTON

The McLean Pluton is located 8 km southeast of the Village of Arden, in Kennebec, Olden and Hinchinbrooke Townships, in Frontenac County. The centre of the pluton is defined by UTM co-ordinates 342100E and 4947500N on NTS map 31 C/10. The pluton is accessible from the Mountain Grove Road south from Highway 7, through the Village of Mountain Grove, and southward to the Hamlet of Mclean. The centre of the pluton is accessible via a bush road which leads westward from the Mountain Grove Road 1 km north of Mclean.

The McLean Pluton is circular in shape, and approximately 10 km in diameter. Topographically, the intrusion is generally flat with moderate outcrop exposure, in the order of 10 to 20 percent. Large portions of the body are inaccessible due to the abundance of swamps. Recent mapping of the pluton was carried out by Wolff (1982).

Primarily granitic to quartz monzonitic in composition, the McLean Pluton is composed of varying amounts of K-feldspar (mainly microcline), plagioclase (andesine to labradorite), quartz, and biotite. Epidote, sphene, and opaque minerals are accessories. Wolff (1982) also describes granodiorite, trondhjemite, and leucocratic granite phases.

Texturally the rocks are equigranular to porphyritic and possess a massive to foliated structure. The western margin of the pluton is highly deformed by a northeast-trending regional shear zone. The intrusion is interpreted to be syn- to late-tectonic in age.

Generally fine to coarse grained, the pluton has local pegmatitic phases.

Although light to dark grey coloured rocks are fairly common, the dominant colour is light to dark pink. Mafic-poor phases (low in biotite) of the pluton seem to be particularly attractive.

Jointing is extremely variable. Intense irregular jointing (<0.5 m spacing) is prevalent throughout most of the pluton, but local areas are only moderately jointed (1 to 2 m spacing). There are usually two or three subvertical to steeply dipping major joint sets accompanied by a well defined horizontal to slightly inclined joint set. Minor joint planes are generally randomly oriented, curved, and discontinuous.

Rocks of the intrusion are generally competent, having only a thin weathered surface, however, some areas seem to be pervasively and deeply eroded. These areas, which are characterized by rocks with a sugary, granular texture, irregular hematite staining, and low physical strength, may represent preglacial erosional surfaces or areas particularly susceptible to meteoric waters.

Inclusions of supracrustal rocks are present throughout most of the pluton, particularly in the western portion, and in close proximity to the intrusive contact. Fine-grained aplitic dikes and pegmatitic phases are also common.

The most promising area for building stone, identified to date, within the McLean Pluton, is located immediately east and west of the main road, approximately 1.5 km north of McLean. Here the stone is medium to dark pink, and medium grained. K-feldspar, quartz, lesser plagioclase, and approximately 5 to 10 percent biotite are the major mineral constituents. The stone is massive to weakly foliated and primarily uniform in colour and texture, with local minor porphyritic phases. Surficial hematite staining and aplitic veining are also minor local features.

Joint intensity is variable, with major sets forming a regular pattern, while less well defined joints reflect an irregular pattern. Major sheeting planes are inclined up to 15° and spaced up to 1 m apart. A subhorizontal exfoliation feature is also evident in this area.

This area does not represent an ideal quarry site because of the physical limitations, although it is indicative of the positive potential for the McLean Pluton as a possible building stone producer.

FUTURE WORK

Reconnaissance assessment will continue in 1987, directed at previously unevaluated plutonic rocks, gneisses, marbles, and limestones. Follow-up detail work will be conducted where warranted.

Active promotion of eastern Ontario stone resources will also become a major phase of the project during 1987. This will primarily be achieved through direct consultation with industry and promotional displays at industry trade shows.

Research into the relevant technology and feasibility of manufactured stone (agglomerates stone, reconstituted stone) may also be conducted during the course of this present study.

ACKNOWLEDGMENTS

Summer personnel, working on the Ontario "Experience 86" Work Program and the UIC-sponsored Section 38 Program, provided invaluable assistance in the field. Independent site evaluations were performed by Vince Bernard, Derrick Benn, and Gordon Vogg. Graham David has recently become involved in property appraisal, and in the production of an Open File Report describing this year's field work.

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073. Eastern Ontario Refractory Potential

A. Mackinnon

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

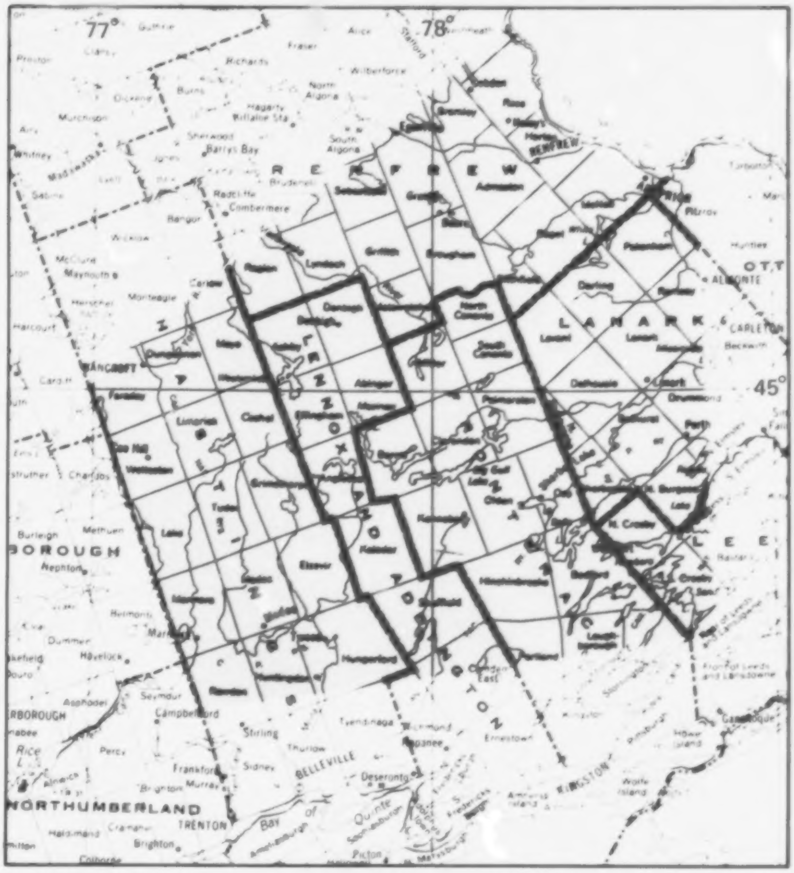
INTRODUCTION

Field work done in 1986 represents part of a multi-year project designed to determine the quantity and quality of refractory industrial minerals available in Eastern Ontario. This was to be accomplished in four stages:

1. through an inventory of resources available and a compilation of the specifications and uses through a detailed literature search
2. through field reconnaissance and geological mapping of refractory mineral occurrences
3. through detailed geological mapping of sites with good potential
4. through collection of bulk samples for testing to determine the quality and quantity of products and co-products that could be beneficiated

Initiation of this project was due primarily to favourable market opportunities for domestic refractories for the replacement of imports. For example, the Canadian chromium supply could be subject to interruption because of our total reliance on imports, which consisted of 10 316 t of chromite ore and 24 827 t of ferro-chromium in 1985. The USSR, South Africa, and the Phillipines represent 61 percent of world mine capacity (Phillips 1986).

Refractories are used in the metal, glass, ceramic, and construction industries. However, the fortunes of the refractory industry are primarily controlled by the iron and steel industry which consumes 50 to 60 percent of the refractories produced (Dickson 1986). The refractories are used as bricks and monoliths for lining furnaces, and as ladles. The demand for Canadian crude steel is expected to remain close to 1985 levels of 14.5 million tonnes.


77°
78°
45°
R E N F R E W
L A N A R K
L E E
BANCROFT
RENFREW
ALMONTE
CARLETON
PETERBOROUGH
NORTHUMBERLAND
TRENTON
BELLEVILLE
KINGSTON
Bay of Quinte
Campbellford
Stirling
Deseronto
Napanee
Gananoque
Perth
Barrys Bay
Combermere
Havelock
Marmora
Brighton
Picton

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

with world consumption projected to grow at 2 percent per annum (McInnis 1986).

Recent technological improvements towards minimizing labour costs and energy demands, while maximizing productivity, have resulted in a need for improved quality and properties of the refractory raw materials (Martinek 1986). This is particularly true of the iron and steel industry, which has experienced a trend toward monoliths and refractories able to withstand increased thermal shock due to faster firing cycles (Burke 1986, Martinek 1986). Secondary refining processes have increased the severity of ladle operating conditions, resulting in a significant trend toward increased consumption of basic refractories such as dolomite. Their share of the ladle refractory market will probably continue to increase as steel quality requirements increase (Copp 1983).

METHODOLOGY

A literature search identified known occurrences of refractory minerals within the project area, and facilitated the compilation of specifications and end-uses.

The bulk of the 1986 field work concentrated on the basic refractories (dolomite/magnesite), while preliminary field work commenced in late August on the aluminosilicate, sillimanite.

Clancy and Benson (1982) determined that chemical purity, resistance of the calcined material to hydration, and specific gravity are measures which may be used to indicate high quality dolomite. Preliminary field reconnaissance of dolomite prospects warranting investigation was based predominantly on chemical purity and, to a lesser extent, on outcrop exposure and accessibility. The most comprehensive sources of data were "Marbles of the Pembroke-Renfrew Area" by Vos and Storey (1979); and "Chemistry of the Grenville Carbonate Rocks, Parts 1 and 2" by Papertzian and Kingston (1982a, 1982b).

ONTARIO DOLOMITE RESOURCES

Precambrian marbles of the Grenville Metasedimentary Belt and Paleozoic carbonate rocks are two potential sources of dolomite within eastern Ontario. Paleozoic carbonate rocks were not investigated as potential sources of refractory glass doloma in the current field study, because of the data obtained on stratigraphic thicknesses and chemical purity by Giles (1976), Hewitt and Vos (1972), Hewitt (1960), and Goudge (1938). Many dolomitic units exist in the Paleozoic rocks of eastern Ontario (i.e. March Formation, Gull River Formation, Oxford Formation), but the data indicate them to be either of insufficient thickness and/or too chemically impure to meet the specifications for use as a refractory mineral (D.A. Williams, Geologist, Ministry of Northern Development and Mines, Tweed, personal communication, 1986). The potential still exists, though, for a variety of other industrial uses such as building stone and construction.

The only Ontario refractory grade doloma presently being marketed is produced from the dolomitic Guelph and Lockport Formations by Steetley Industries Limited from their Dundas Quarry in Hamilton. Production is on the order of 350 000 tpa burnt products, of which 90 000 tpa is refractory monoliths (Coope 1981). A detailed description of the Dundas Quarry and its geology can be found in Goudge (1938), Hewitt (1960), and Hewitt and Vos (1972).

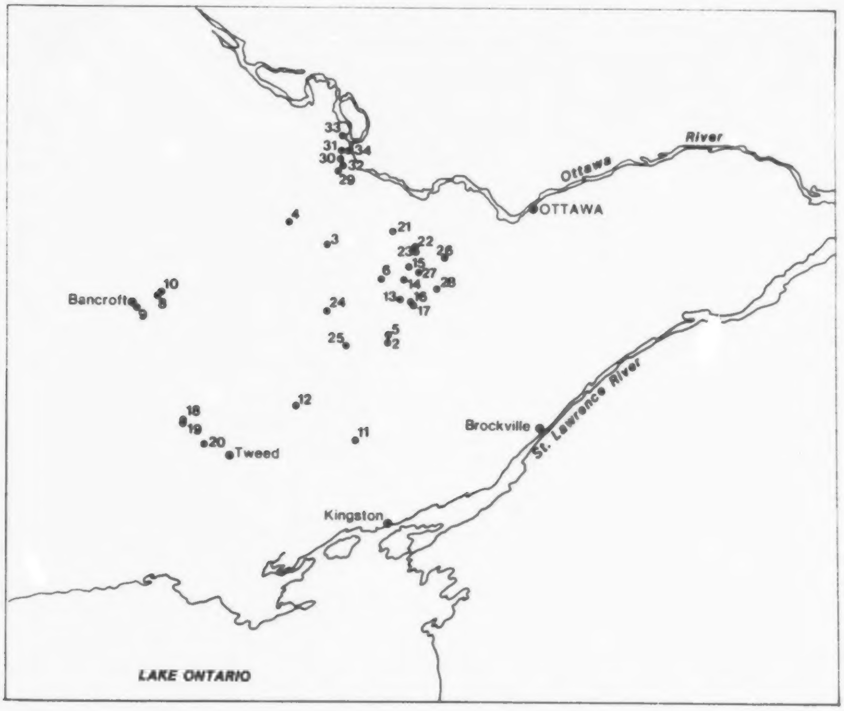


Figure 073.1. *Location of Study Areas.*

TABLE 073.1: DOLOMITE CHEMICAL ANALYSES (from Papertzian and Kingston 1982 [P&K]; Vos and Storey 1979 [V & S]).

Location Number	Sample Number	Data Source	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	L.O.I.**
1	528	P&K	29.39	20.63	1.36	0.45	0.08	45.5
2	1915	P&K	29.30	19.05	0.92	0.46	0.31	45.60
3	PM-44	V&S	30.2	20.7	1.17	0.2	0.1	47.3
4	MA-13	V&S	30.7	21.1	0.5	0.2	0.01	47.0
5	766	P&K	28.90	19.8	0.06	0.19	0.15	46.50
6	1663	P&K	30.00	20.2	1.14	0.40	0.26	44.30
7	1675	P&K	29.80	20.60	0.00	0.17	0.17	45.40
8	B12	P&K	31.4	20.2	0.4	0.6	—	—
9	419	P&K	29.84	20.76	0.19	0.53	0.09	47.0
*10			—	—	—	—	—	—
11	1370	P&K	29.7	20.70	0.41	0.14	0.18	43.60
12	439	P&K	29.95	20.90	0.39	0.19	0.14	46.30
13	1531	P&K	30.20	19.60	0.65	0.22	0.19	47.20
14	1553	P&K	30.40	19.5	0.35	0.25	0.20	48.60
15	1580	P&K	29.80	20.00	0.35	0.19	0.16	47.70
16	1656	P&K	29.80	20.50	0.29	0.27	0.12	45.50
17	1658	P&K	29.80	20.10	0.06	0.17	0.13	45.20
18	42	P&K	29.62	20.89	0.88	0.16	0.27	45.10
19	44	P&K	29.96	21.03	0.01	0.10	0.18	46.60
20	2	P&K	29.62	20.55	1.28	0.08	0.08	39.20
	3	P&K	29.85	20.81	0.01	0.12	0.07	40.40
21	PM-117	V&S	30.1	21.2	1.45	0.3	0.3	46.9
22	1817	P&K	30.0	20.2	1.03	0.12	0.08	46.10
23	1819	P&K	30.20	20.10	0.00	0.26	0.08	46.30
24	PM-135	V&S	30.1	20.7	1.27	0.6	0.1	46.7
25	708	P&K	29.4	20.5	0.05	0.22	0.05	46.30
26	1745	P&K	29.40	19.10	0.85	0.21	0.29	46.30
27	1758	P&K	29.50	20.50	0.43	0.19	0.23	48.00
28	1804	P&K	30.00	20.20	0.32	—	0.16	—
29	R3	V&S	31.2	19.4	0.3	0.2	0.1	—
30	127	V&S	31.28	21.04	0.2	0.1	tr	—
31	R1	V&S	29.2	16.4	10.5	0.2	0.2	—
*32			—	—	—	—	—	—
*33			—	—	—	—	—	—
*34			—	—	—	—	—	—
Pure Dolomite			30.41	21.87	—	—	—	—

*no chemical analysis available
**L.O.I. - Loss on Ignition

Precambrian marbles show good potential as sources of high-purity doloma, and were the objective of this past field season.

FIELD WORK

Thirty-four areas were selected for preliminary reconnaissance. The locations and chemical analyses of samples from these sites are presented in Figure 073.1 and Table 073.1.

Many of the prospects examined were difficult to assess because of limited outcrop exposure, which consisted predominantly of either: low-lying outcrops, limited in extent; or roadcuts, with limited to nonexistent exposure away from the road. This is a common phenomenon with marbles in the Grenville due to the nature of weathering, and is particularly prevalent with calcitic marbles. Vos and Storey (1979) noted a higher degree of variability in the marble belts nearer the unconformity separating Grenville supracrustal rocks (Late Precambrian) from the older rocks of the Grenville Structural Province (Middle Precambrian), than in wide belts, like those occurring in Horton, Ross, McNab, and Darling Townships. The authors, however, did not exclude the possibility of the thinner marble belts containing economic deposits. Vos and Storey's (1979) study, and the current field work, both conclude that, in general, thick marble belts appear to contain a greater proportion of pure marble than thinner belts. This is evident in Figure 073.1, with the clustering of study areas in Lanark County and Ross Township.

At the time of writing, several areas show potential in terms of purity; however, large tonnage situations have not as yet been identified. Selective

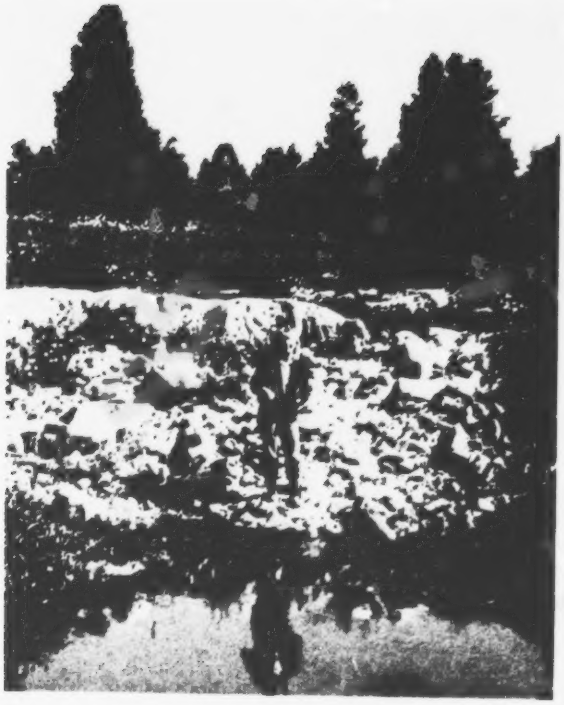


Photo 073.1. .Study Area 19.

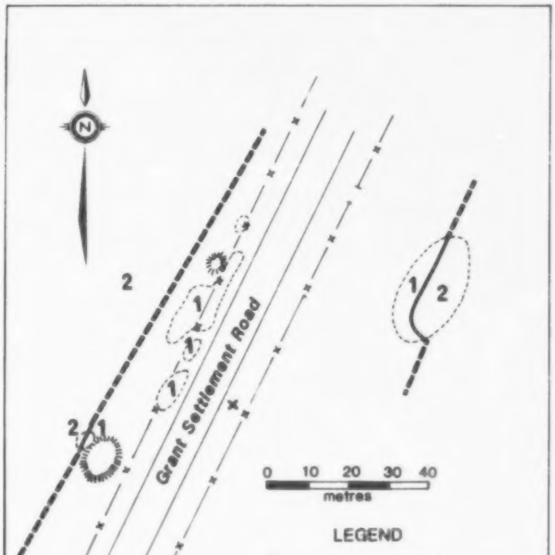


Figure 073.2. Sketch map of Study Area 33.

mining of smaller high purity deposits may prove to be economically feasible. Two areas that may show potential for this type of operation are Study Areas 19 and 33 (Figure 073.1, Table 073.1).

Study Area 19 is located in lot 1, concession 13, Madoc Township, approximately 1.5 km west of Fox Corners on County Road 11 (approximately 17 km north of the Town of Madoc). Two small inactive quarries occur within the study area, and are approximately 9.5 m by 13.0 m and 7.0 m by 10.0 m in size. Photo 073.1 illustrates one of these small quarries at this location. Overburden thickness appears to be less than 1 m, with fair to poor outcrop exposure. The dolomitic marble is intensely jointed and contains iron oxides along the joint planes. The iron staining is attributed to seepage during pre-Paleozoic weathering and from basal Paleozoic deposits, and locally only extends 1 to 2 metres below the surface (Springer 1983). Veins up to 1 cm in width of medium- to coarse-grained calcite were observed as a minor constituent within the marble. Generally, the texture appeared to be uniform and massive, although in places the rock appears lineated. The observed width of the pure dolomite zone appears to be 50 m at this locality.

Study Area 33 is situated in lot 10, concession 11, Ross Township, approximately 3.7 km northeast of Millars Corner on Grant Settlement Road. A narrow band of fairly pure dolomitic marble, trending roughly parallel to the road, occurs here. Flanking both sides is a highly siliceous dolomitic marble containing abundant quartz and tremolitic veins and knots, up to 0.5 m in thickness. Figure 073.2 is a sketch map of the area. Outcrop exposure is poor, although overburden thickness is probably less than 2 m.

The dolomitic marble is fine grained and white in colour, with a granular, massive texture. Acicular tremolite occurs as a minor constituent within this unit. The width of this band appears to be 50 m at this locality.

USES AND SPECIFICATIONS

Dolomite is used by the iron and steel, glass, nonferrous metals, ceramic, chemical and petrochemical, construction, agricultural, and paint/plastic/rubber industries in a variety of products. It is used to manufacture magnesia refractories, high magnesia lime (dolime), special cements, flux for ferro-alloys, and magnesium metal (Anani 1984). To serve as a refractory material, dolomite has to be dead-burned or sintered at temperatures around 1800°C in order to drive off the carbon dioxide. This results in a more inert, denser (3.0 to 3.2 g/ml) product called "dead burned dolomite" or doloma (Coope 1981). The presence of boron, sulphur, and phosphorus, even in small quantities, is extremely undesirable (Clancy and Benson 1982, Hewitt 1960).

Presented in Table 073.2 are typical chemical analyses of commercial dolomite ores that are currently being produced. Comparison with Table 073.1 reaffirms eastern Ontario's potential, at least in terms of chemical purity, for high-grade doloma production.

For use as metallurgical flux, impurities should not exceed 3 percent, with sulphur and phosphorous

TABLE 073.2: CHEMICAL ANALYSES OF TYPICAL COMMERCIAL DOLOMITES (after Goudge 1938, Vos and Storey 1979, Coope 1981). All values are weight percent.

	MgO	CaO	Fe_2O_3	Al_2O_3	SiO_2	L.O.I.	Intended Usage
UK (Steetley)	20.80	30.10	0.50	0.20	0.50	47.20	Refractories
Eire (Quigley)	20.75	30.80	0.80	0.15	1.50	46.00	Seawater magnesia
Belgium (Merlemont)	21.80	30.10	0.35	0.45	0.40	47.00	Refractories or flux
W. Germany (Wulfrath)	20.20	31.50	0.40	0.40	0.50	47.00	Refractories
Norway (Norw. Talc)	21.71	30.31	0.04	0.03	—	47.51	Filler/extenders
France (BMP)	21.11	31.21	0.01	0.02	—	47.42	Filler/extenders
Spain (Iberdol)	21.70	31.10	0.10	0.02	0.05	47.00	Glass
Greece (Sealistiri)	21.11	31.11	0.10	0.08	0.30	46.90	Refractories
India (Tata I and S)	21.15	30.20	0.65	0.45	1.30	46.03	Blast furnace flux
USA (Basic)	21.60	30.50	0.05	0.10	0.20	47.00	Refractories or flux
Ontario (Chromasco)	21.04	31.28	0.10	Tr	0.20	—	Magnesium metal
Ontario (Steetley)	20.78	30.63	0.55	0.28	0.62	—	Refractories or flux

kept to a minimum (Hewitt 1960). Combined MgO and CaO should exceed 96%, with less than 0.1% Fe_2O_3 and less than 4% combined SiO_2 and Al_2O_3 for applications in the glass industry (Hewitt 1960).

The ceramics industry requires a minimum of 30% CaO and 21.4% MgO, with R_2O_3 less than 0.2%, of which Fe_2O_3 must not exceed 0.03%. The milled product must not exceed 5% hydroscopic water for use as feed stuff (Konta 1982).

In agriculture, ground dolomite is applied to neutralize soil acidity and to counteract acidity from the use of fertilizers (i.e. urea). Adding dolomite has resulted in a 15 to 40% increase in crop yield (Anani 1984).

The rate of hydration of cement can be accelerated by adding up to 40% by weight fine-grained dolomite (Anani 1984).

The paint/plastic/rubber industry uses white dolomite as an important filler/extender material. Lesser quantities are used in coal mine dusting, incorporation into mineral wool, ceramic pacifers, and pollution control (water purification/sewage treatment/flue gas desulphurization). Dolomite is also used as a building stone, and most quarry operators produce aggregate as either a coproduct or as their sole product.

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074. Wollastonite in Marmora Township, Hastings County, Southern Ontario

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This project is part of the Canada-Ontario Mineral Development Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

INTRODUCTION

Field work commenced in early September on a recent discovery of wollastonite located in Marmora Township, concession VIII, on lots 5, 6, and 7. Preliminary investigation confirmed significant quantities of wollastonite over a minimum strike length of 1200 m.

Wollastonite is a calcium metasilicate ($CaSiO_3$), with a theoretical composition of 48.3% CaO and 51.7% SiO_2. It forms as a contact metamorphic mineral within impure limestone near intrusive bodies of granite or other acidic rocks, as the result of metasomatism of calcareous sedimentary rocks, or by crystallization of certain magmas. The following reaction:

$$CaCO_3\text{(calcite)} + SiO_2\text{(silica)} = CaSiO_3\text{(wollastonite)} + CO_2\text{(carbon dioxide)}$$

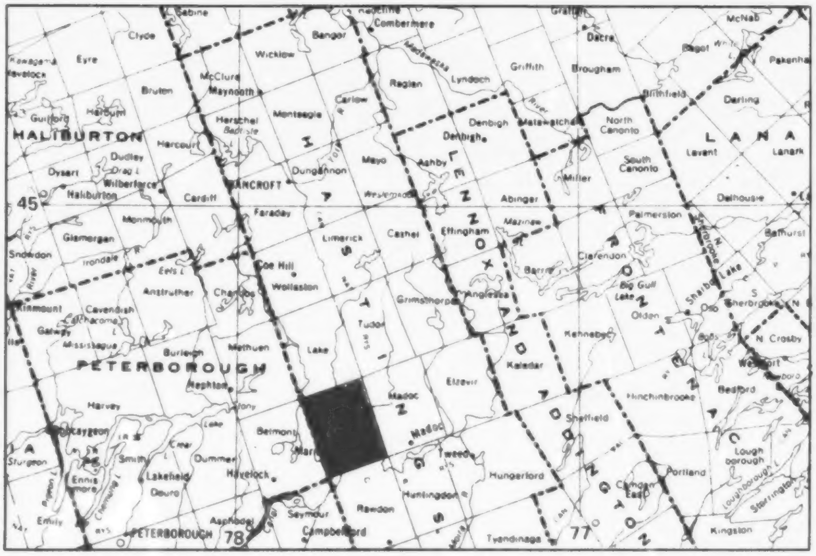
produces wollastonite when silica emanations from a granitic intrusion react with calcite in limestone (Elevatorski 1983).

Wollastonite is used as a filler in ceramics, plastics, paints, adhesives, insulating materials, sealants, resins, bonded adhesives, and wall boards. It is also used as an extender to replace nonfibrous materials and asbestos, as metallurgical flux, and in the manufacture of glass (Smith 1981; Choate 1978).

World market demands are supplied by only a few countries, with the two American producers, NYCO and R.T. Vanderbilt Company Incorporated, accounting for 66 percent of world production, and lesser quantities being supplied by Finland, India, and Mexico. Small operations are also present in Namibia, New Zealand, Japan, and Turkey. There are deposits in China and the Soviet Union, but only limited information is available on them (Smith 1981; Power 1986). Figure 074.1 shows the distribution of producers and potential world reserves. Canada does not presently produce wollastonite, although excellent market opportunities exist for a Canadian deposit. Wollastonite's potential in the future appears very promising, particularly in the long fibre market which has recently experienced a great deal of investment (Power 1986).

REGIONAL GEOLOGY

The study area is located near the southwestern boundary of the Central Metasedimentary Belt of the Grenville Province (Wynne-Edwards 1972). Figure 074.2 shows the general geology of Marmora Township. The formation names have been generalized by Bartlett and Moore (1985), based on extrapolations made from Bartlett's (1983) work in Belmont Township. Middle Ordovician sedimentary rocks (Shadow Lake, Gull River, and Bobcaygeon Formations) occupy areas to the north and west of the study area, and the Deloro granite occupies the area to the east. The Marmora Formation, the major carbonate unit in the study area, consists of calcitic and dolomitic carbonates, interlaminated carbonates and siliceous



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

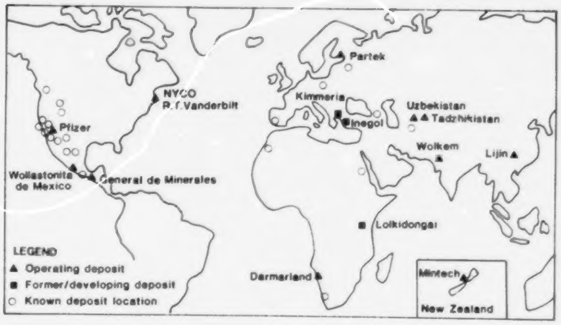

Partek
NYCO
R.T.Vanderbilt
Pfizer
Kimmeria
Uzbekistan
Tadzhikistan
Inegol
Wolkem
Lijin
Wollastonita de Mexico
General de Minerales
Lolkidongai
Darmarland
Mintech
New Zealand
LEGEND
▲ Operating deposit
■ Former/developing deposit
○ Known deposit location

***Figure 074.1** Location of world wollastonite producers and reserves (from Power 1966).*

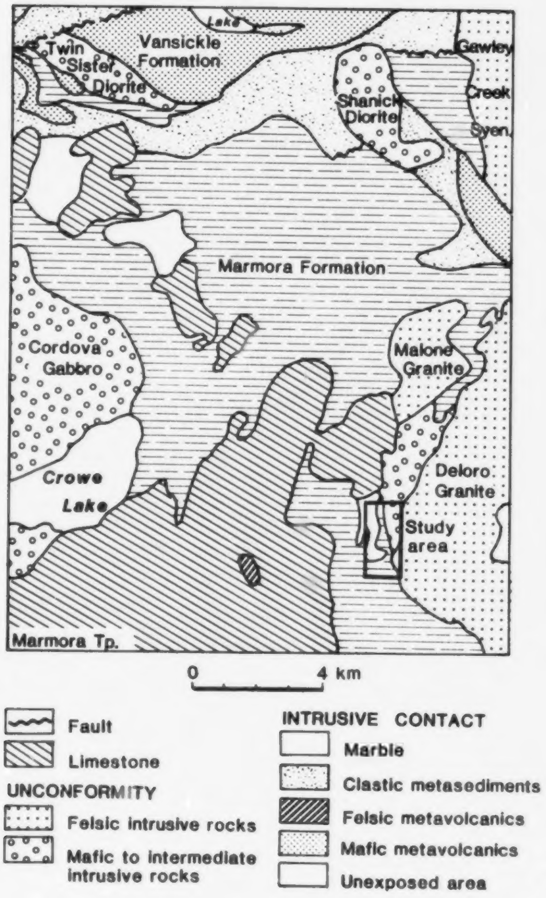

Lake
Twin Sister Diorite
Vansickle Formation
Gawley Creek Syen.
Shanick Diorite
Marmora Formation
Cordova Gabbro
Malone Granite
Crowe Lake
Deloro Granite
Study area
Marmora Tp.
0
4 km
Fault
Limestone
UNCONFORMITY
Felsic intrusive rocks
Mafic to intermediate intrusive rocks
INTRUSIVE CONTACT
Marble
Clastic metasediments
Felsic metavolcanics
Mafic metavolcanics
Unexposed area

***Figure 074.2** Generalized geological map of the study area (after Bartlett and Moore 1985).*

TABLE 074.1: X-RAY RESULTS, MARMORA STUDY AREA.

Sample No.	Mineralogy Identified
W-3	Wollastonite, Calcite
W-13	Calcite, Serpentine
W-14	Wollastonite, Calcite
W-16	Wollastonite, Calcite
W-18	Wollastonite, Calcite
W-22	Calcite, Serpentine, Tremolite
W-24	Quartz, Tremolite, Epidote
W-25	Calcite, Serpentine, Dolomite (?)
W-33	Epidote, Feldspar
W-47	Quartz, Epidote

clastic sedimentary rocks, mudstones, and conglomerates. However, not all of these lithologies are represented in the study area.

The region is located in a metamorphic low, known as the "Hastings Basin" or "Hastings Region" (Lumbers 1964), which is an area of middle greenschist metamorphism centred around Millbridge.

STUDY AREA

The Marmora study area is located in Marmora Township, concession VIII, on lots 5, 6, and 7, approximately 5 km east of Marmora. Access to the property is via Highway 7 or from the old Madoc-Marmora road.

LOCAL GEOLOGY

The rocks within the study area were generalized into six groups: wollastonite-bearing calcitic marble, dark green siliceous marble, siliceous hornfels, gabbro-diorite intrusive rocks, granite, and amphibolite dikes. Ten samples were analyzed by X-ray methods to identify the mineralogy (Geoscience Laboratories, Ontario Geological Survey, Toronto), and the results are presented in Table 074.1. Four samples (W-3, W-14, W-16, W-18) were selected from the wollastonite-bearing zone, three (W-13, W-22, W-25) from the dark green siliceous marble unit, and three (W-24, W-33, W-47) from the siliceous hornfels unit.

Preliminary investigation indicates that the wollastonite-bearing zone is continuous over a minimum strike length of 1200 m and attains a maximum width of 100 m in the central portion of the study area where it appears to have been folded. The extent of the wollastonite-bearing zone is illustrated in Figures 074.3 and 074.4. This zone is relatively unique in that, unlike those of NYCO and most other world producers, it is essentially a two mineral assemblage (i.e. wollastonite and calcite). Individual grains of wollastonite up to 6 cm can be commonly observed. The weathered surface is a grey or black colour and has a pitted appearance; the calcite stands out in relief. The wollastonite-bearing zone probably originally consisted of a relatively pure calcitic limestone before the silicification process occurred; this is supported by the lack of other impuri-

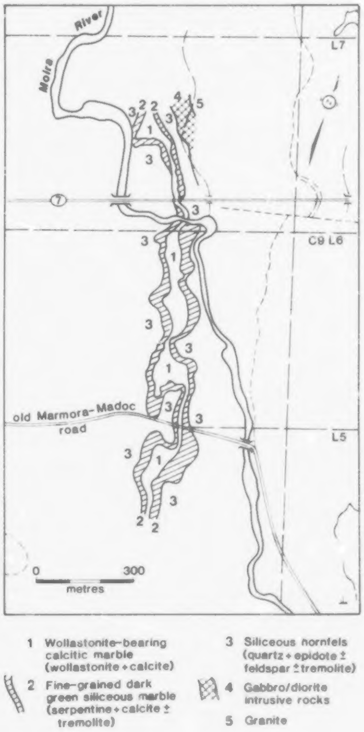

Moira River
L7
7
C9 L6
old Marmora-Madoc road
L5
0
300
metres
1 Wollastonite-bearing calcitic marble (wollastonite + calcite)
2 Fine-grained dark green siliceous marble (serpentine + calcite ± tremolite)
3 Siliceous hornfels (quartz + epidote ± feldspar ± tremolite)
4 Gabbro/diorite intrusive rocks
5 Granite

Figure 074.3 *Detailed central portion of the wollastonite zone.*

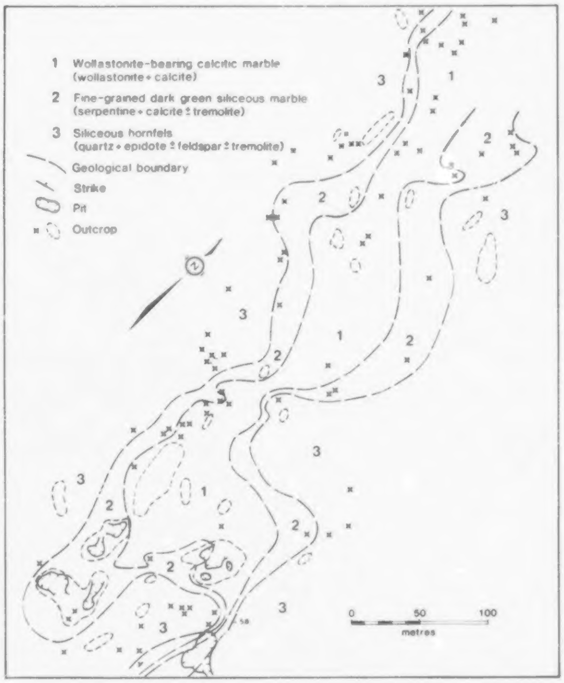

1 Wollastonite-bearing calcitic marble (wollastonite + calcite)
2 Fine-grained dark green siliceous marble (serpentine + calcite ± tremolite)
3 Siliceous hornfels (quartz + epidote ± feldspar ± tremolite)
Geological boundary
Strike
Pit
Outcrop
7
0
50
100
metres

Figure 074.4 *Wollastonite zone.*

ties in the zone. Two amphibolite dikes intrude the wollastonite-bearing marble in the northern section near Highway 7.

In contact with the wollastonite-bearing unit is a fine-grained, dark green siliceous marble dipping 55 to 60°. The mineralogy consists of calcite and serpentine±tremolite±dolomite(?). This unit was found particularly useful in locating the wollastonite-bearing zone where outcrop exposure was poor, since it generally occurs as a transitional zone between the siliceous hornfels and wollastonite zones. The colour is predominantly light to dark green, although locally a mottled grey and green or grey marble could be observed. It was quarried by Stocklosar Marble Company as a source of terrazzo chips, as evidenced by the numerous pits on this property (Verschuren *et al.* 1986). Occurring within this unit is a brown banded and brecciated calcitic marble containing barite veins, which was observed next to the wollastonite zone near Highway 7.

The siliceous hornfels unit is a fine-grained siliceous rock adjacent to the green siliceous marble. Mineralogically it contains quartz and epidote±tremolite±feldspar±sulphides. Texturally it varies from massive to banded (in places brecciated), and from a dark grey cherty appearance to a green and brown mottled appearance. The weathered surface varies from white to orange. At the time of writing, no thin section results were available.

Gabbro to diorite intrusive rocks and fine-grained granite occur along the northeastern edge of the study area.

ACKNOWLEDGMENTS

The author wishes to gratefully acknowledge the invaluable assistance of Graham David, who assisted in preliminary field mapping. Bill Hicks of the Geoscience Laboratories, Ontario Geological Survey, Toronto, proved very helpful in X-ray analysis of the samples on short notice.

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INTERDISCIPLINARY PROGRAMS

The Opapimiskan Lake Project

The Black River—Matheson (BRIM) Program

075. Opapimiskan Lake Project: Precambrian Geology of the Opapimiskan-Forester Lakes Area, District of Kenora, Patricia Portion

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INTRODUCTION

This is the final year of a three-year integrated geoscience survey of the North Caribou Lake Belt, an area of Archean supracrustal rocks which forms part of the Sachigo Subprovince in northwestern Ontario (Figure 075.1). This project is designed to update and expand the geological database available on this area, and to assess its largely unexplored mineral potential.

In 1984, the first year of the project, multidiscipilinary surveys in the northwestern part of the area involved bedrock and surficial mapping, mineral deposits and aggregate assessment studies, and reconnaissance till prospecting for gold. These activities are reported by Breaks *et al.* (1984).

In the second year of the project, Precambrian and Quaternary mapping was carried out to the southeast of the area surveyed in 1984. Detailed mineral deposit studies were continued in the western part of the belt. The results of these activities are reported by Breaks *et al.* (1985) and Piroshco and Shields (1985).

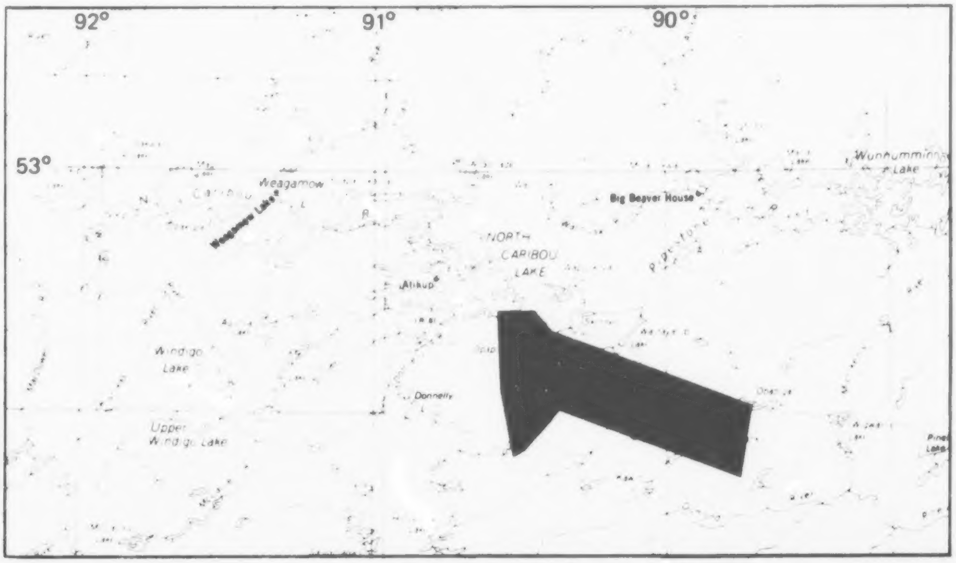
The North Caribou Lake Belt was covered in the first part of 1985 by a geophysical program including airborne electromagnetic and total field magnetic surveys. Maps based on these surveys were released in 1985 (OGS 1985).

Precambrian mapping in 1986 continued southeastward from the area surveyed in 1985 (Breaks *et al.* 1985). The study area covers approximately 555 km^2 and its centre is roughly 120 km north of Pickle Lake. Access to most of the area is by float- or ski-equipped aircraft from Pickle Lake. Preliminary findings are summarized in this report, and a preliminary map based on this survey will be released early in 1987.

MINERAL EXPLORATION HISTORY

The earliest exploration activity in the map area dates back to 1941. At that time grab samples of mineralized quartz vein reported to contain over 5.0 ounces gold per ton instigated a staking rush by several mining companies and individuals (Resident Geologist's Files, Ministry of Northern Development and Mines, Red Lake). The initial discovery occurred near Wesley Lake and later became part of the Jardine Syndicate claim group.

The map area witnessed only sporadic exploration until the early 1960s when Rio Tinto Canadian Exploration Limited and The International Nickel Company of Canada Limited (INCO) both undertook major reconnaissance programs designed to test massive sulphide, nickel, and gold potential (Assessment Files Research Office, Ontario Geological Survey, Toronto). A complete summary of this work, and other early exploration, is given in Thurston *et al.* (1979, p.74-97). In 1962, discovery of gold by the Musselwhite brothers at Opapimiskan Lake in highly deformed banded iron formation (Thurston *et al.* 1979,



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

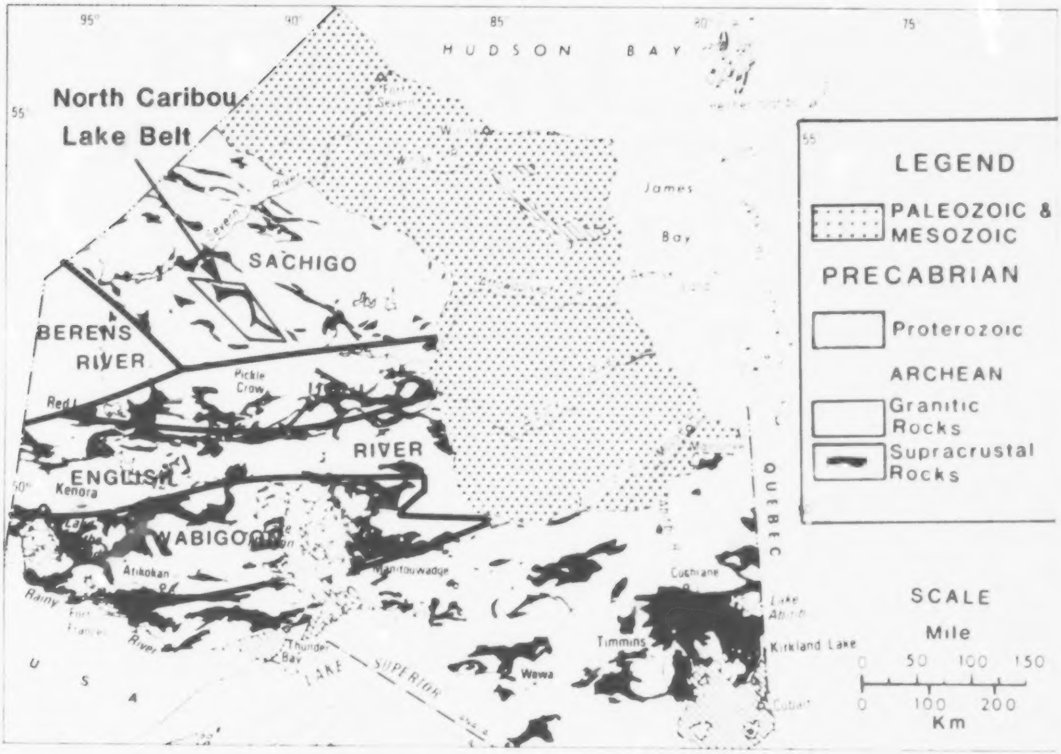

95°
90°
85°
80°
75°
55°
50°
HUDSON BAY
North Caribou Lake Belt
Fort Severn
Winisk
Severn River
SACHIGO
BERENS RIVER
Red L
Pickle Crow
RIVER
ENGLISH
Kenora
WABIGOON
Atikokan
Rainy River
Fort Frances
Thunder Bay
LAKE SUPERIOR
Manitouwadge
Wawa
Timmins
Cochrane
Kirkland Lake
Lake Abitibi
Cobalt
James Bay
QUEBEC
U S A
LEGEND
PALEOZOIC & MESOZOIC
PRECABRIAN
Proterozoic
ARCHEAN
Granitic Rocks
Supracrustal Rocks
SCALE
Mile
0 50 100 150
0 100 200
Km

Figure 075.1. *Location of the North Caribou Lake "Metavolcanic-Metasedimentary" Belt and its position within the Superior Province.*

p.85-86) renewed interest in the North Caribou Lake Belt. In 1973, the Musselwhite brothers optioned the property to a consortium including Dome Mines Limited, Dome Petroleum Limited, Canadian Nickel Company Limited (Canico), Esso Minerals Canada, and Lacana Mining Corporation. Since that time, this group has been involved in an intermittent program of geophysical surveying, geochemical sampling, prospecting, geological mapping, trenching, and 180 diamond drill holes; this culminated in an announcement of the discovery of major gold deposits (The Northern Miner, March 5th, 1981), containing in excess of 1 million tons grading 0.20 ounce gold per ton.

During the 1985 field season, ground work including line cutting and surface geology was carried out by the same group of companies. Dome Mines Limited recently announced (The Northern Miner, August 11, 1986) the discovery of a new gold deposit 2 km east of their Musselwhite Property. Initial results from 20 drillholes indicate an average grade of 0.26 ounce gold per ton over a 4.5 m width (Oracle Resources Limited, Annual Report 1985).

Van Horne Gold Exploration Incorporated/Moss Resources Limited conducted a 12-hole, 1500 m diamond drilling program at their Opapimiskan Lake property in the Summer of 1985 (The Northern Miner, September 16, 1985). Multiple high grade zones were discovered by this drilling program; further drilling is planned to commence shortly on the property (H.J. Hodge, President, Moss Resources Limited, personal Communication).

During 1984 and 1986, Tex-U.S. Oil and Gas Incorporated completed a 598 m diamond drilling program in six holes on their property, approximately 2.0 km northeast of Wesley Lake (Resident Geologist's Files, Ministry of Northern Development and Mines, Sioux Lookout). They reported a gold value of 0.47 ounce gold per ton over 0.61 m, encountered in a sheared gabbro. As a result of this drilling program an additional 17 claims were staked by Tex-U.S. Oil and Gas Incorporated to the east of their property in 1986.

GENERAL GEOLOGY

Mapping by the authors in 1984 (Breaks *et al.* 1984) and 1985 (Breaks *et al.* 1985) confirmed the northwestern and central part of the North Caribou Lake Belt consists, for the most part, of a thick clastic metasedimentary sequence, the Eyapamikama Lake Metasediments. This sequence is flanked to the north by the North Rim Metavolcanics and to the south by South Rim Metavolcanics. As these major lithological units extend into the 1986 study area, the same informal stratigraphic names are used in this report.

SOUTH RIM METAVOLCANICS

This mafic to felsic metavolcanic sequence is traceable in the report area for 32 km along the western part of the North Caribou Lake Belt. Its southern termination occurs near the middle of Barrigar Lake. In the Opapimiskan Lake area, these volcanic rocks found on the Musselwhite and Van Horne Gold Exploration Incorporated gold properties (Breaks *et al.* 1985) lie in contact with extensive and complexly folded grunerite-magnetite chert banded iron formations (BIF).

The main lithlogies are fine- to medium-grained, massive and pillowed mafic flows. Pillow structures are widespread and commonly flattened to the extent that they are of little use as stratigraphic facing indicators.

Massive flows vary from fine to coarse grained, and their original textures are variably overprinted by the development of dark green hornblende porphyroblasts up to 6 mm in diameter.

Felsic and intermediate flows and pyroclastic units are distributed throughout the South Rim Metavolcanic sequence, but are rare within the North Rim Metavolcanics. These felsic and intermediate rocks occur sparingly in very thin localized units. The largest area of exposure (200 by 600 m) of these units occurs along the western shoreline of Opapimiskan Lake, otherwise these units are typically 10 m or less in thickness.

Mafic metavolcanics in the Libert-Barrigar Lake area are comprised of pillowed, variolitic, massive flows and amphibolite. The most common metamorphic mineral assemblage consists of chlorite+actinolite+plagioclase±epidote.

Highly sheared ultramafic flows containing talc+carbonates±tremolite±serpentine were encountered at the southern tip of Libert Lake and to the west of Barrigar Lake. A narrow ultramafic pillowed unit is exposed on a small unnamed lake to the west of Barrigar Lake. Pillows average 1 m long and 20 cm wide with 2 to 4 mm selvedges. Carbonate alteration in selvedges and in pillow cores are noticeable in places.

Lensoid units of felsic flows, tuffs, and volcaniclastic rocks are exposed on the southeastern shore of Libert Lake.

NORTH RIM METAVOLCANICS

This predominantly mafic metavolcanic assemblage forms the eastern edge of the North Caribou Lake Belt in the report area and extends for 11 km from the northern limit of the area to Opapimiskan Lake. It tapers progressively southwards from 3000 to 1500 m in width. Southeast of Opapimiskan Lake the sequence, due to paucity of exposure, can not be confidently extended. It is possible that these metavolcanics and the adjacent Eyapamikama Lake Metasediments are infolded and now occur within the core zone of the Van Horne antiform.

The North Rim Metavolcanics have been subjected to intense ductile deformation, as evidenced by a penetrative foliation and lineation. Relatively massive hornblende-porphyroblastic mafic metavolcanics are also widespread, commonly intercalated with highly foliated amphibolites. Primary structures, in form of pillows and varioles, are only rarely evident.

OPAPIMISKAN-MARKOP METAVOLCANICS

In the vicinity of Opapimiskan Lake, the North Rim Metavolcanics wedge out, and are supplanted to the southeast by the Opapimiskan-Markop Metavolcanics (Figure 075.2). This possibly older, geochemically more primitive, subaqueously deposited assemblage is overwhelmingly mafic to ultramafic in composition. Felsic and intermediate metavolcanics are apparently absent. The metavolcanics are macroscopically intercalated with clastic metasediments on a one-to-one

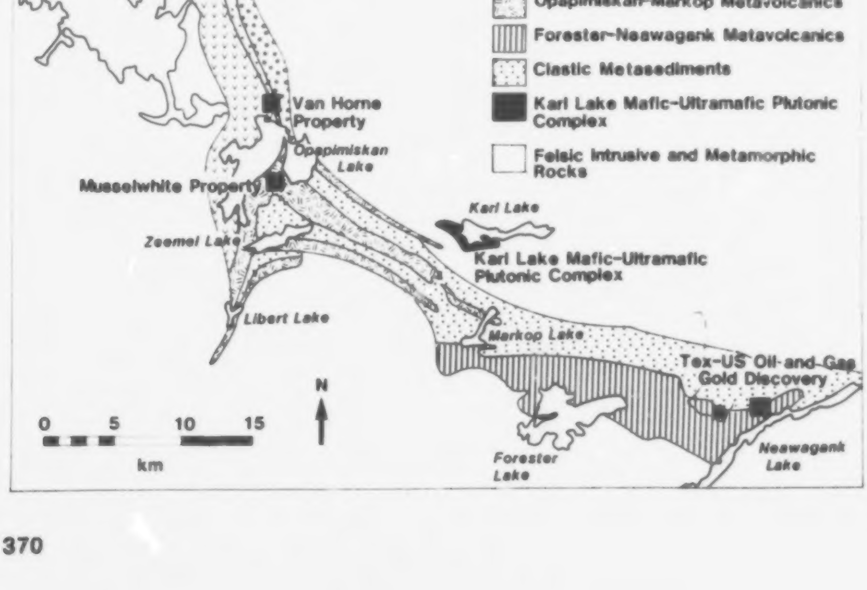

North Caribou Lake
Akow Lake
South Rim Metavolcanics
North Rim Metavolcanics
Opapimiskan-Markop Metavolcanics
Forester-Neawagank Metavolcanics
Clastic Metasediments
Karl Lake Mafic-Ultramafic Plutonic Complex
Felsic Intrusive and Metamorphic Rocks
Van Horne Property
Opapimiskan Lake
Musselwhite Property
Karl Lake
Zeemel Lake
Karl Lake Mafic-Ultramafic Plutonic Complex
Libert Lake
Markop Lake
Tex-US Oil-and-Gas Gold Discovery
N
0
5
10
15
km
Forester Lake
Neawagank Lake

Figure 075.2. *General geology of the Opapimiskan-Forester Lakes area, showing properties mentioned in the text.*

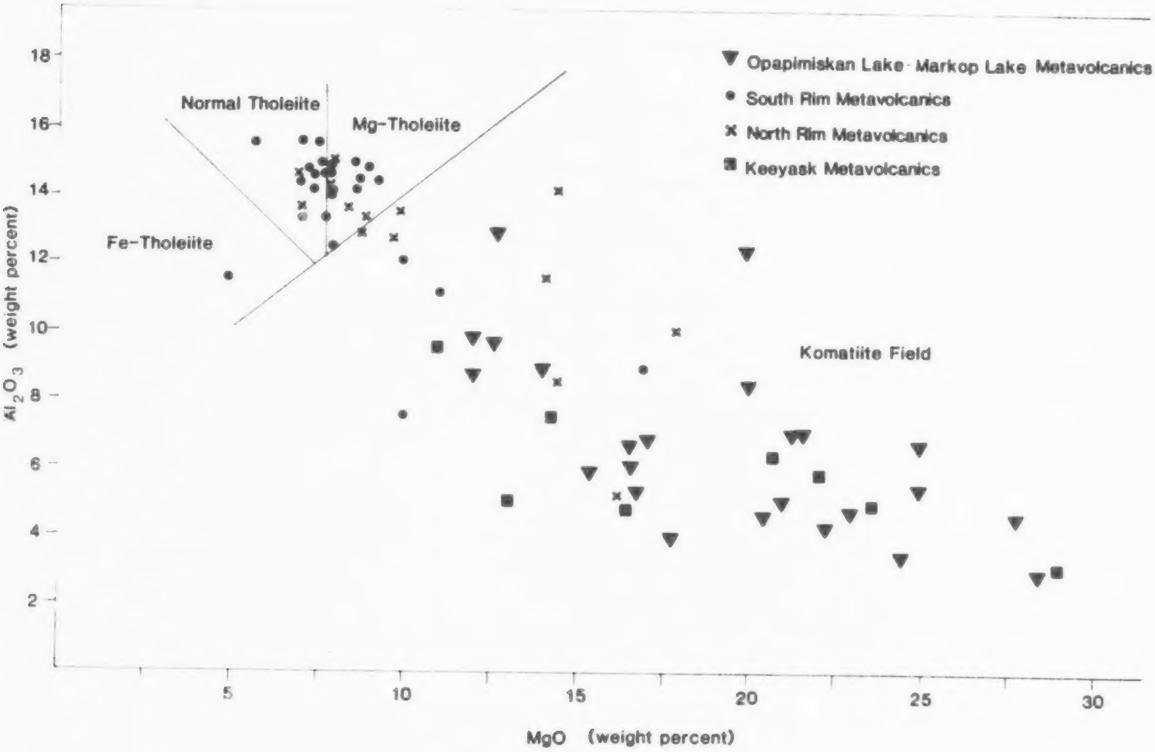


Figure 075.3. *MgO-Al_2O_3 plot for various metavolcanic assemblages from the North Caribou Lake Belt (diagram after Viljoen et al. 1982, p.76).*

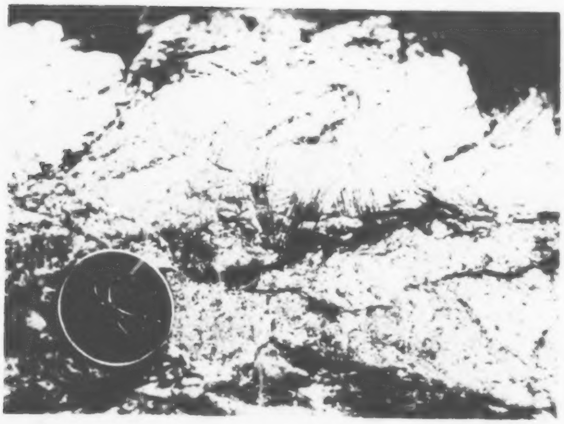


Photo 075.1. *Spinifex texture in auto-brecciated komatiitic flow at Pipestone River.*

basis between Opapimiskan and Markop Lakes. These rocks are traceable, albeit discontinuously, for 20 km from the Musselwhite gold Property (Opapimiskan Lake) to the northern arm of Markop Lake.

An abundance of komatiitic metavolcanics is the prime characteristic of this lithological group (Figure 075.3); they are similar compositionally to the Keeyask Lake Metavolcanics at the western end of Eyapamikama Lake (Breaks *et al.* 1984).

Preserved primary features include pillows, pillow breccia, varioles, and massive flows, exhibiting monolithic angular flow-top breccia. Spinifex and polysuture textures are only rarely preserved, for example, near the Pipestone River (Photos 075.1 and 075.2).

Of interest as a potential regional stratigraphic marker lithology are the variolitic komatiitic metavolcanics exposed 1.5 km east of Zeemel Lake and between Libert Lake and the east-flowing segment of Paseminon River.

More typically, the komatiitic metavolcanics are highly deformed, granoblastic or decussate in texture, and medium grained. They are composed essentially of actinolite with minor chlorite and plagioclase. A narrow, poorly exposed unit of ultramafic and mafic metavolcanics appears to define the northeastern contact of the North Caribou Lake Belt between Opapimiskan Lake and Pipestone River. This unit, which has a width of approximately 400 m, has mainly been delineated on the basis of aeromagnetic data (OGS 1985): a conspicuous curvilinear aeromagnetic pattern is related to magnetite-bearing komatiitic metavolcanics (24.9% MgO, 10.7% total Fe as Fe_2O_3, and 5.4% Al_2O_3), which are poorly exposed 2 km east of Opapimiskan Lake. The high MgO contents of this unit suggests a closer affiliation to the Opapimiskan-Markop Metavolcanics than to the North Rim Metavolcanics which do not exhibit such elevated MgO contents (Figure 075.3).

FORESTER-NEAWAGANK METAVOLCANICS

This metavolcanic sequence occupies the eastern end of the North Caribou Lake Belt (Figure 075.2), and consists dominantly of pillowed, massive, and amygdaloidal mafic metavolcanics. Komatiites are apparently rare, in contrast to the metavolcanics between Opapimiskan Lake and Markop Lake.

At the western end of Forester Lake, mafic metavolcanics comprise highly lineated, black amphibolites in which however, highly stretched pillow structures; intact selvedges are still recognizable. Subtly lineated, medium- to coarse-grained hornblende-porphyroblastic mafic metavolcanics occur widely in the Sage Lake area. These rocks may be confused with metamorphosed mafic plutonic rocks, however, their intercalation with grunerite-magnetite-chert banded iron formation(s), and the widespread presence of pillow structures, are evidence of their volcanic protolith.

At Neawagank Lake, metavolcanics are dominantly comprised of fineto coarse-grained mafic pillowed and massive flows. Massive to weakly foliated, coarse-grained flows either represent flow centres or subvolcanic intrusions. Relatively highly deformed mafic metavolcanics mapped as amphibolite were encountered close to the contact with plutons in the southern margins of the belt, and on the northwestern shore of Neawagank Lake.

Two felsic metavolcanic units were mapped in this sequence. One quartz fragmental unit, about 100 m northeast of Wesley Lake, is 60 m thick, and the other, located 250 m north of the western shore of Neawagank Lake, is a 3 m thick subvolcanic unit interbedded with pillowed mafic metavolcanics.

CLASTIC METASEDIMENTS

Eyapamikama Lake Clastic Sequence

This sequence, which occupies the axial portion of the belt between northern map limits and Opapimiskan Lake, consists of a 0.3 to 1.2 km wide mixed sequence composed of very thinly bedded wackes, feldspathic arenite, biotite-chlorite pelites, amphibole-rich wackes, and local intercalated felsic metavolcanics.

The metasediments change south of Akow Lake from predominantly andalusite-cordierite-staurolite metapelites to a sequence with a higher proportion of arenites and wackes.

Adjacent to their western contact with pillowed mafic metavolcanics (North Rim Metavolcanics) the amphibole-rich metawackes compose about 80% of the sequence. With increasing distance from this contact metawackes bands decrease rapidly to 10% of the sequence accompanied by a concomitant increase in the proportions of feldspathic arenite and wacke.

Zeemel-Pipestone-Heaton Clastic Sequence

Rocks of this sequence are extensively developed but poorly exposed in the map area. Southeast of Zeemel Lake, a continuous 1.5 to 5.5 km wide band of clastic metasediments, infolded with the Opapimiskan-Markop Metavolcanics, is traceable for 50 km to Obabigan Lake.

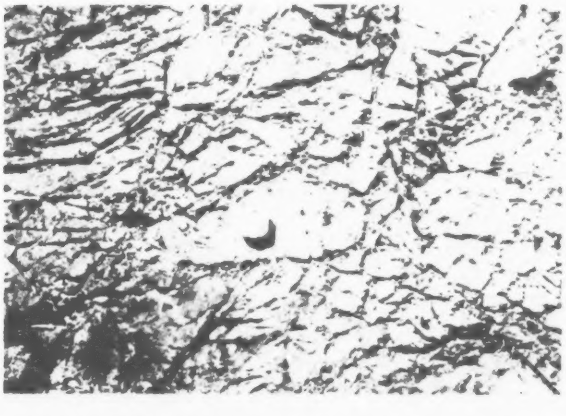


Photo 075.2. *Polysuture structure in komatiitic metavolcanics near Pipestone River.*

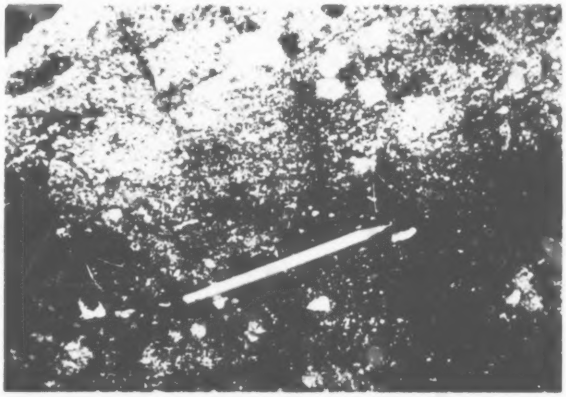


Photo 075.3. *Quartz-rich metawacke west of Pipestone River exhibiting abundance of angular, mainly granule-size, quartz and occasional cobbles of fine angular to subrounded vein quartz.*

Main rock types include muscovite-biotite metawacke, and pelite, feldspathic arenite, quartz wacke, and quartz arenite. Clast and matrix-supported granule to boulder, polymictic conglomerate are locally present as along and west of Pipestone River. At the Pipestone River locality, such conglomerates lie in sheared contact with highly altered, spinifex-textured, monolithic autoclastic mafic to ultramafic breccia. Top determinations from locally crossbedded and graded granule conglomerate units suggest that the metasediments overlie komatiitic metavolcanics.

Texturally immature quartz wackes, quartz arenite, and feldspathic arenites, are especially abundant between Pipestone River (Photo 075.3) and Heaten Lake.

Main framework grains in arkosic arenite and wacke beds are composed of quartz (40 to 90%), plagioclase (20 to 55%), metavolcanic lithic grains (5 to 15%), and accessory fuchsite.

Primary depositional structures in these rocks include trough cross stratification, basal scour surfaces, and graded bedding.

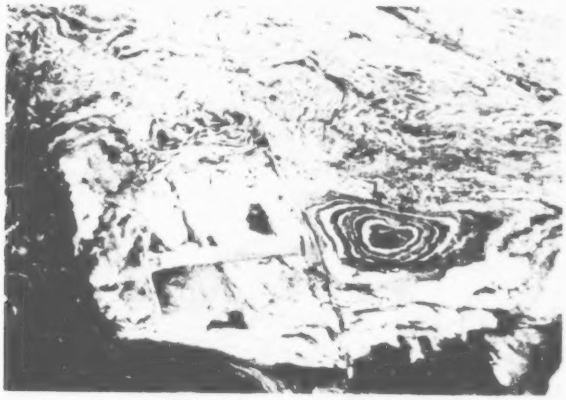


Photo 075.4. *Basin-shaped interference fold structure in magnetite-chert BIF hosted by Opapimiskan-Markop komatiitic metavolcanics near Graff Lake.*

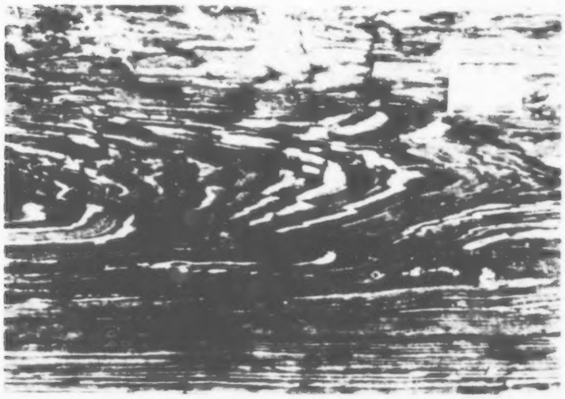


Photo 075.5. *F_2 fold closure demonstrating an axial plane parallel to shearing within chert-magnetite banded iron formation in the northeastern Graff Lake area.*

CHEMICAL METASEDIMENTS

Chemical metasediments are extensive in the Opapimiskan-Markop and Forester-Neawagank Metavolcanic sequences. Elsewhere they are rare.

Previously unmapped grunerite-magnetite-chert banded iron formations, up to 13 m in width, occur east of Graff Lake. These units, which are interlayered with komatiitic metavolcanics, represent a southeastward continuation of a similar sequence on the Musselwhite gold Property, and exhibit identical deformation histories (*see* Breaks *et al.* 1985) featuring mesoscopic basin and dome interference folds (Photo 075.4).

Banded iron formation at Graff Lake is tightly folded and has been affected by intense axial planar clevage and associated shearing (Photo 075.5). Along zones of shearing in BIF units, grunerite has formed at the expense of magnetite, and sulphide minerals have been introduced.

About 1 km northwest of Forester Lake there is a 15 m wide, laminated to very thinly bedded, magnetite-chert BIF unit. The BIF is in contact with komatiitic metavolcanics and contains layers of garnet-actinolite-chlorite, similar to BIF on the Musselwhite gold Property (Breaks *et al.* 1985).

Just north of Sage Lake, folded grunerite-magnetite-chert BIF, approximately 12 m thick, enclosed in hornblende-porphyroblastic mafic-ultramafic metavolcanics, is exposed over a length of 100 m.

Iron formation was not observed in the Neawagank Lake area. However, two major bands of iron formation striking northeastward were deduced from aeromagnetic maps (OGS 1985).

The first band, which has a strike length of over 1.5 km, lies just south of Wesley Lake. The second band is situated immediately north of the western shore of Neawagank Lake. Exposed length of this band is 5 km.

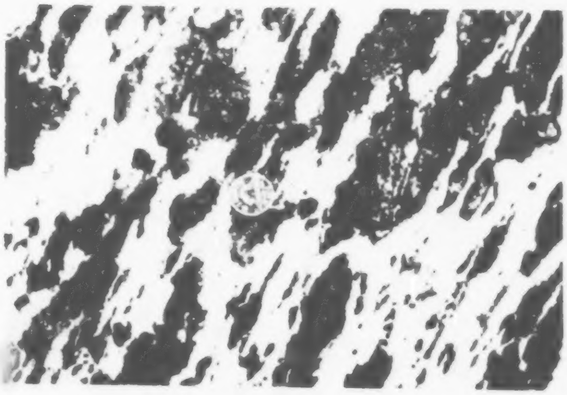


Photo 075.6. *Anorthositic gabbro from the Karl Lake Plutonic Complex.*

The southwestern extension of the second band appears to be complexly folded and sheared in several places. (*see* Chart A, Figure 075.4 in back pocket)

Three drillholes at the Jaeger Resources Limited property, in the northwestern Neawagank Lake area, intersected a predominantly oxide facies BIF with minor interbanded sulphide zones (Adams 1985).

KARL LAKE PLUTONIC COMPLEX

This previously unrecognized, moderately magnetic, metamorphosed, mafic-ultramafic intrusive mass (Figure 075.2), is situated over the western end of Karl Lake where it has intruded tonalitic gneisses and a small remnant of high grade clastic metasediments. The main rock types of this intrusion are pyroxenite, gabbro, and amphibolite. Anorththositic gabbro (Photo 075.6) and anorthosite are considerably less common. Preserved magmatic layering was encountered in one locality on the Pipestone River (second set of rapids north from Karl Lake). Amphibolite, which is fine grained and similar in mineral composition to the gabbro phase of the intrusion, occurs to the north of Karl Lake, and along the Pipestone River just west of Karl Lake, and may actually represent more intensely recrystallized variants of the metagabbro.

MAFIC AND ULTRAMAFIC PLUTONIC ROCKS

These rocks are mainly distributed between the Pipestone River and Neawagank Lake where they have intruded clastic metasediments, tonalitic gneiss, and metavolcanics of the Opapimiskan-Markop and Forester-Neawagank assemblages. Generally, the intrusions are small; the largest mass is the 2 by 5 km Karl Lake Plutonic Complex. Metagabbro masses are present west of the Pipestone River, Markop Lake, and near Neawagank Lake. These masses are massive, coarse-grained, hornblende-plagioclase rocks which exhibit little compositional variation, and are relatively resistant to deformation. Near Neawagank Lake, these rocks show gradation into quartz gabbro characterized by 5 to 10% blue quartz.

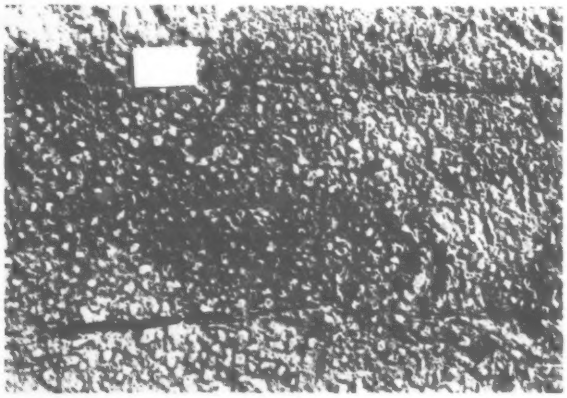


Photo 075.7. *Nodular ultramafic metaplutonic rock situated near Forester Lake.*

A previously undocumented small (15 by 70 m) mass of ultramafic rock, showing spectacular nodules, was delineated 2 km northwest of Forester Lake (Photo 075.7). This lithology has been thoroughly converted to secondary serpentine+talc. There has however been excellent preservation of 2 mm to 4 cm diameter nodules (talc pseudomorps of olivine), composing between 55 and 95% of the rock. Cumulate layering is evident. Nodule-free layers are commonly intercalated with some layers in which there is a gradual increase in nodule size normal to the layering. This reflects a link between growth and nucleation rates.

FELSIC TO INTERMEDIATE INTRUSIVE ROCKS

These intrusions range in composition from hornblende-biotite tonalite, through garnet-muscovite trondhjemites and S-type granite, to granites and granite pegmatites. By far the most common types encountered in the project area were biotite and hornblende-biotite tonalites. These occur in the bounding batholiths northeast and northwest of Opapimiskan Lake, north of Karl Lake, south of Zeemel and Forester Lakes, and east of Libert and Barrigar Lakes.

Commonly, these intrusive rocks are foliated and lineated, quite often exhibiting a folded contact with the belt. Xenoliths and thin slivers of amphibolite are common in tonalites proximal to belt margins.

To the north and northeast of Graff Lake, north of Libert Lake, and northwest Barrigar Lake, metavolcanics and metasediments are intruded by, and complexly folded with, early garnet-muscovite dikes and S-type granites (white K-feldspar+quartz+plagioclase+muscovite+garnet±tourmaline). Extensional stresses have caused boudinage and rotation of early trondhjemite dikes.

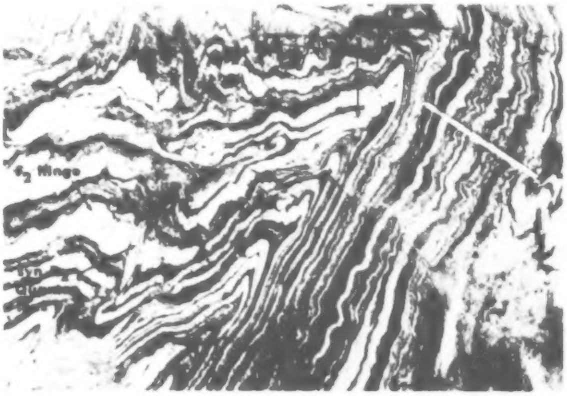


Photo 075.8. *F_1 tight to isoclinal folds in magnetite-chert BIF (hinge marked by coin) refolded by F_2 open folds (marked by arrow) with associated axial planar cleavage and quartz lenses. F_3 folds parallel to pencil at right, are responsible for Z-shaped open buckling, mainly in the limb areas of earlier folds.*

Myriad granite pegmatite dikes occur within all rock types proximal to batholith/belt margins. These are massive and undeformed. Several pegmatite phases may be seen in any particular outcrop, but no consistent relationships are apparent.

METAMORPHISM

Metamorphic grade varies from upper greenschist to lower amphibolite facies.

Poor exposure of pelitic units across the map area precludes delineation of isograds, however, in the Forester-Markop Lake area, pelitic metasediments containing staurolite+almandine garnet occur in contact with mafic metavolcanics of hornblende+plagioclase assemblage. This suggests a temperature of approximately 550°C and a load pressure of 3 to 4 kb (Hyndman 1972).

Mafic metavolcanics typically contain hornblende+plagioclase with minor actinolite. Chlorite appears mostly retrograde, however, in some localized areas a chlorite+epidote+plagioclase assemblage indicates a lower metamorphic grade. Higher metamorphic grade, characterized by black hornblende+plagioclase found proximal to belt margins, reflects the presence of a contact aureole imposed during granitoid intrusion.

STRUCTURAL GEOLOGY

All major rock types in the map area have been affected by at least three distinct phases of folding and several periods of intense shearing and mylonitization.

Evidence for an early deformation (D_1) can be documented in rare situations; for example, the presence of refolded isoclines in BIF (Photo 075.8) (Breaks *et al.* 1985) on the Dome Group's Musselwhite Property, on Grunerite Island, in the Graff Lake area, and as rootless intrafolial folds in quartz veins hosted by ultramafic and mafic metavolcanics in the northwestern Opapimiskan Lake area.

Initial morphology of F_1 folds is difficult to assess, as their present isoclinal shapes are probably the result of rotation of fold limbs into parallelism with F_2 fold limbs.

D_2 was a major event in the area. It is manifested as close to open, asymmetric Z and S mesoscopic folds, with near vertical axial planes and interlimb angles typically between 70° and 100°. F_2 mesoscopic folds are well preserved in biotite-rich metasediments in the Barrigar Lake area, in the BIF exposure at Opapimiskan Lake (Breaks *et al.* 1985), and in the Graff Lake area. In more ductile rocks, such as pelites, ultramafic, and chlorite-rich mafic metavolcanics, the D_2 event is mainly apparent as a penetrative S_2 foliation. Accompanying penetrative linear fabric elements are defined by mineral and pillow stretching lineations S_0-S_2 intersection in BIF, and F_2 fold hinges.

Stereoplots of orientation of probable L_2 mineral lineations and associated F_2 hinge lines display wide variation throughout the map area (Chart A, figure 075.4). Development of post-D_2 ductile to brittle shear zones may be an explanation for the regional scattering of the L_2 lineation orientation in some areas.

Effects of a D_3 event are only observed in the BIF exposures at the Musselwhite Property. It is mainly evident as mesoscopic, asymmetric, F_3 folds which are open (90° to 125° interlimb angle), Z-shaped, with vertical axial planes (Breaks *et al.* 1985). Superposition of F_1-F_2-F_3 and F_2-F_3 fold elements are revealed in several exposures on the Musselwhite Property (Breaks *et al.* 1985), and in the Graff Lake area. Interference of F_1-F_2 folds in BIF exposure at Graff Lake, yields Type 1 basin and dome structural patterns (Ramsay 1967) (Photo 075.4).

Two major, previously undocumented, zones of ductile shearing, with left lateral sense of movement, were delineated between Akow and Opapimiskan Lakes; these probably formed after the D_2 tectonometamorphic event. Major lithological contacts control the disposition of these shear zones. One shear zone is developed along the axial portion of North Caribou Lake Belt (North Rim Metavolcanics-Eyapamikama Lake Clastic Metasediments contact) where it extends for 10 km southward from Akow Lake; the other (Dinnick Lake Fault) occurs along the eastern belt boundary between Dinnick Lake, and an unnamed lake situated approximately 1 km southwest of Wapuskeya Lake.

The best exposures of the first shear zone mentioned are located near the western shoreline of an unnamed lake. There, a 300 m wide zone, showing intense ductile deformation, cuts a mixed metavolcanic-metasedimentary package and coincides with a trend reversal in D_2 mineral stretching lineations (Figure 075.4).

In the second important shear zone (Dinnick Lake Fault), a 500 m wide tonalitic unit is wedged between the eastern boundary of the North Rim Metavolcanics and a thin, isolated sliver of previously unrecognized pillowed mafic metavolcanics. Main rock types are biotite-rich tonalite, mylonite, and protomylonite.

There is also a wide zone of intense shearing along the central portion of Neawagank Lake. Regional foliation trends are deflected into this zone from the west and are asymptotic to the zone along the northern shore of Neawagank Lake. On the northwestern shore of Neawagank Lake, shearing is represented by an extensively mylonitized tonalitic gneiss in contact with banded amphibolite gneiss.

ECONOMIC GEOLOGY

Approximately 280 samples were submitted to the Geoscience Laboratories, Ontario Geological Survey, Toronto, for analysis of gold (2 ppb sensitivity), silver, arsenic, antimony, copper, lead, zinc, and in certain cases tungsten, lithium, tin, boron, fluorine, rubidium, tantalum, and niobium. The material currently being analyzed includes metavolcanics and metasediments with sulphide mineralization, quartz veins containing sulphide mineralization and/or tourmaline and/or carbonate and/or albite, barren quartz veins, banded iron formation, and garnetiferous rocks.

TABLE 075.1: ANALYSES OF MINERALIZED SHEAR ZONE, ALBITIC GRANITOID DIKE, TOURMALINE-CHLORITE-BIOTITE METASOMATIC SEGREGATIONS, D_2 QUARTZ VEIN, AND UNMINERALIZED BIF FROM MUSSELWHITE NO. 1 GOLD SHOWING, NEAR OPAPIMISKAN LAKE.

	Au (ppb)	Ag (ppm)	As (ppm)	Sb (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Li (ppm)	Sn (ppm)	Rb (ppm)	Ta (ppm)	Nb (ppm)	F (ppm)	B (ppm)	Nb/Ta	Na_2O%	K_2O%
Albitized Granitoid Dike																	
OP153-1B	1840	<2	19	0.6	225	11	24	66	<0.8	215			100	17			
1D	790	<2	1050	5.2	144	18	82	71	0.9	120			130	21			
1S	600	<2	23	2.8	13	<10	33	34	87.1	230	140	14	670	5	0.1	4.61	0.53
Tourmaline-Chlorite-Biotite Selvedges																	
1C	15	<2	47	1.3	24	<10	98	375	18.5	980			4160	41			
1T	310	<2	2.0	1.9	5	<10	8	26	38.6	145	80	12	320		0.15	3.88	0.22
1U	1740	<2	6500	55	13	<10	96	49	309	16	80	15	5240	330	0.18	0.19	0.27
Shear Zone Mineralized with Asp, po, py along Mafic Metavolcanic/BIF contact																	
FWB 85 0002																	
OP153-1X	5950	2	57	2.8	148	96	41										
1Z	340	<2	61	2.2	41	<10	62										
1W	6710	<2	2300	13.9	302	<1	38										
Quartz Vein Concordant to D_2 Axial Plane																	
OP153-1R	980	<2	5	1.5	7	<10	16										
Unmineralized Grunerite-Magnetite-Chert BIF[1]																	
WB85-0001	3	<2	10	3.6													

[1] 2.5 m channel sample taken across uniformly banded but not intensely folded BIF adjacent to mineralized shear zone (FWB 85-0002). Possibly representative of background values at this showing.

TABLE 075.2: Pt, Pd, Au, Cu, Ni, Cr, and Zn ANALYSES FOR SULPHIDE MINERALIZATION ASSOCIATED WITH THE KARL LAKE MAFIC-ULTRAMAFIC PLUTONIC COMPLEX.

	Pt(ppb)	Pd(ppb)	Au(ppb)	Cu(ppm)	Ni(ppm)	Cr(ppm)	Zn(ppm)
	Karl Lake Chalcopyrite-Pyrrhotite Locality						
A26-12 I	5	55	35	910	57	136	92
12 II	3	26	30	875	59	85	106
12 III	8	74	70	1520	50	107	108
12 IV	5	35	25	790	53	77	106
12 V	31	22	100	1420	57	58	110
12 VI	6	17	13	495	39	51	107
	Pipestone River Chalcopyrite-Pyrite-Pyrrhotite Locality						
Z25- 4 I	<1	<1	3	<5	7	277	<5
4 II	3	28	17	765	17	94	27
4 III	5	12	40	1420	44	146	32
4 IV	3	14	70	3880	11	84	18

Gold mineralization occurs within the map area in the following associations.

1. grunerite-magnetite-chert BIF hosted by Opapimiskan-Markop mafic to ultramafic metavolcanics (e.g. Musselwhite Property, van Horne Occurrence, Paseminon River Occurrence)
   a. along sulphide-mineralized D_2 shear zones
   b. in garnet-tourmaline albite-rich granitoid dikes intruded subconcordantly to D_2 axial planar cleavage in BIF
   c. in sulphide-bearing quartz veins emplaced concordantly to D_2 axial planar cleavage in BIF
2. tourmaline-carbonate quartz veins emplaced pre-D_2 in the South Rim Mafic Metavolcanics (e.g. Kenpat No.1 vein)
3. D_2 shear zones mineralized with arsenopyrite, pyrite, and pyrrhotite in mafic metaplutonic rocks (e.g. Tex-US Oil and Gas Incorporated Gold Discovery)
4. quartz veins in D shear zones mineralized with arsenopyrite, pyrite, chalcopyrite, and sphalerite (e.g. Sage Lake Gold Occurrence)

A detailed examination at the Musselwhite No 1 gold showing indicates that gold mineralization occurs in four habitats (Table 075.1).

Gold mineralization associated with arsenopyrite+pyrite-bearing albitized granitic pegmatite dikes and attendant metasomatic selvedges exhibit a clear association with anomalous levels of rare metals, in particular Li, Rb, Ta, and Sn.

Tantalum contents of the dikes vary from 80 to 140 ppm, considerably elevated above the estimated crustal abundance of 2 ppm (Mason 1966). The Nb/Ta ratio in these dikes of 0.1 to 0.18 departs significantly from the crustal average of 10 (Mason 1966, p.45-46), also indicating significant geochemical fractionation.

To the authors' knowledge the metallogenic association of gold with rare metals has not been previously recognized in the Superior Province and this potential should be more closely examined in other areas.

Gold-bearing, albite-rich dikes, which occur at the Musselwhite No.1 gold showing, as reported by Breaks *et al.* (1985, p.274), quite likely originated from a small mass of tourmaline-garnet-muscovite granite and granitic pegmatite situated 7 km to the southeast. This small stock, approximately 0.5 km^2 in area, is enveloped by muscovite-biotite pelites and wackes and possibly originated via anatexis of such rocks at a deeper crustal level. Pre-D_2 boudinaged dikes of identical rock, with biotite-tourmaline metasomatic haloes, occur in garnet-biotite pelite on the nearby Paseminon River.

Widespread distribution, albeit in scant quantities, of pre-D_2 segregations enriched in tourmaline and biotite are notable in the Opapimiskan-Markop Metavolcanics, especially in massive komatiitic flows and pillow selvedges in mafic metavolcanics located in the Graff Lake area and on the Musselwhite gold Property.

This event of boron-potassium metasomatism possibly relates to volatile-charged, albitized granitic pegmatite dikes emanating from S-type granitoid masses similar to that described above.

Veins of similar material were emplaced discordant to the S foliation in metasediments near Libert Lake which were subsequently overprinted by close to tight D folds.

GALENA-BEARING QUARTZ-CARBONATE VEINS

the northeastern portion of claim 369752 on the Musselwhite Property, a 45 m wide, highly deformed quartz-carbonate vein in mafic metavolcanics contains mesoscopic fine-grained galena. A grab sample submitted to the Geoscience Laboratories, Ontario Geological Survey, Toronto, for analysis, was found to contain 1140 ppb Au, 59 ppm Ag, 80 ppm As, 43 ppm Sb, 8.65% Pb, 24 ppm Zn, and 24 ppm Cu.

SHEAR ZONE-HOSTED GOLD MINERALIZATION

Major ductile to brittle shear zones are widely developed within the Opapimiskan Lake area, the area north of Akow Lake, and in the Markop and Neawaoank Lakes areas. These zones, which are commonly marked by "trains" of electromagnetic conductors of variable intensity, should be thoroughly investigated for gold mineralization. North of Opapimiskan Lake are noteworthy anomalous gold values up to 550 ppb (Assessement Files Research Office, Ontario Geological Survey) associated with arsenopyrite within a prominent shear zone controlled by the contact of North Rim Metavolcanics with the Eyapamikama Lake Clastic Metasediments.

In the Neawagank Lake area, gold occurs in an east-west-trending shear zone northeast of Wesley Lake. Gold is associated with massive to disseminated (1 to 2%) arsenopyrite+pyrite±pyrrhotite, veinlets which are hosted by sheared, quartz gabbro to diorite. Gold values of 0.074 to 0.42 ounces per ton were recorded from the Resident Geologist's Files, Ministry of Northeren Development and Mines, Sioux Lookout. Quartz veins and veinlets from the same shear zone were noted by the field party to contain only small amounts of disseminated sulphide mineralization. Bands of iron formation delineated from aeromagnetic maps (OGS 1985) appear to be complexly folded and sheared in several places. These bands should be considered prime targets for gold mineralization.

PLATINUM AND PALLADIUM IN MAFIC-ULTRAMAFIC METAPLUTONIC ROCKS

Anomalous trace levels of platinum and palladium were encountered in previously undocumented sulphide-mineralized amphibolitic rocks occurring in two localities within the Karl Lake Plutonic Complex (Table 075.2). Several assays indicate anomalous trace levels of gold, palladium, and platinum; this plutonic complex, as well as others mapped in the area, merit an examination with regards to these metals.

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076. Structural Geology and Gold Mineralization of the Eyapamikama Lake Area of the North Caribou Lake Greenstone Belt, District of Kenora (Patricia Portion)

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INTRODUCTION

In this final year of the three-year Opapamiskan Integrated Geoscience Program, involving staff from Mineral Deposits, Precambrian Geology, and Engineering and Terrain Geology Sections, the Mineral Deposits Section concentrated its field work in the Eyapamikama Lake area of the North Caribou Lake Greenstone Belt (Figure 076.1). The study area is located some 180 km north of Pickle Lake and is best accessed from that community by float-equipped aircraft.

PREVIOUS WORK

Geological mapping within the Eyapamikama Lake area prior to 1984 is summarized by Breaks *et al.* (1984). During 1984, this area was mapped at a 1:15 840 scale by the Precambrian Geology Section (Bartlett *et al.* 1985). The mapping outlined a number of areas where problems of stratigraphy and structure are not resolved. These areas are coincident with a number of the known gold occurrences and were also the target of recent staking activity. Also during 1984, the Mineral Deposits Section carried out a preliminary examination of the geology of gold occurrences in the belt. The studies by the Precambrian Geology and Mineral Deposits Sections served as a base for work carried out by the latter in 1985, which included regional and detailed mapping in the areas of several known gold occurrences (Piroshco and Shields 1985).

PURPOSE OF STUDY

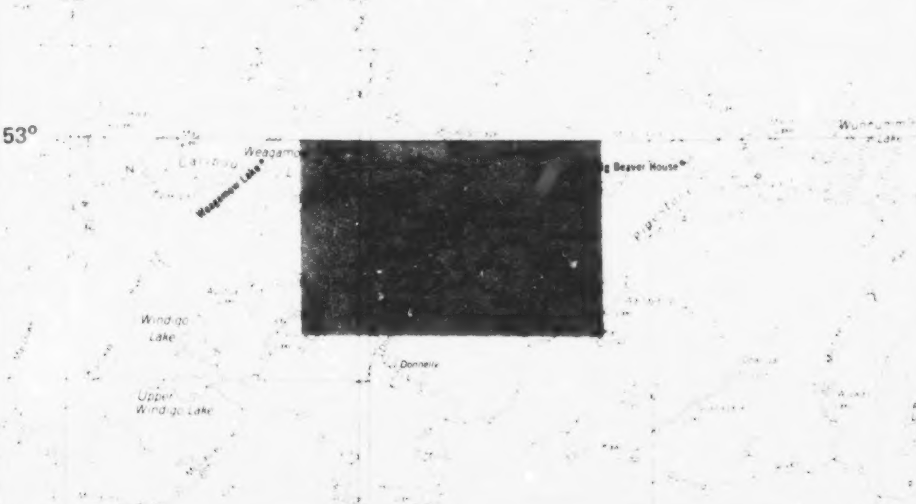
The purpose of this study is to enhance the regional interpretation of the geology through detailed mapping in problem areas and to provide a complete evaluation of gold mineralization potential in the Eyapamikama Lake region, particularly in areas which have not been subject to exploration activity. In particular, the emphasis of this study, which includes both regional and detailed field work and petrography, is on determining the relationship of gold mineralization to patterns of metamorphism, deformation, and alteration.

The Eyapamikama Lake area was chosen for these examinations, rather than areas to the southeast (e.g. Opapamiskan Lake), because of its wider variations of metamorphic facies, structural styles, and lithologies.

This summary deals mainly with the detailed field work component of the program.

MINERAL EXPLORATION

During the 1986 field season, geological mapping, lithogeochemical sampling, and prospecting were carried out by Agnico-Eagle Mines Limited on their Capella Lake Property. In addition, Northern Dynasty Explorations Limited completed selective geochemical soil surveys, lithogeochemical sampling, and prospecting on their Arseno Lake Property (Figure 076.1). Approximately 150 claims were staked and recorded in the northwestern and eastern



LOCATION MAP

Scale 1: 1 548 000 or 1 inch to 25 miles

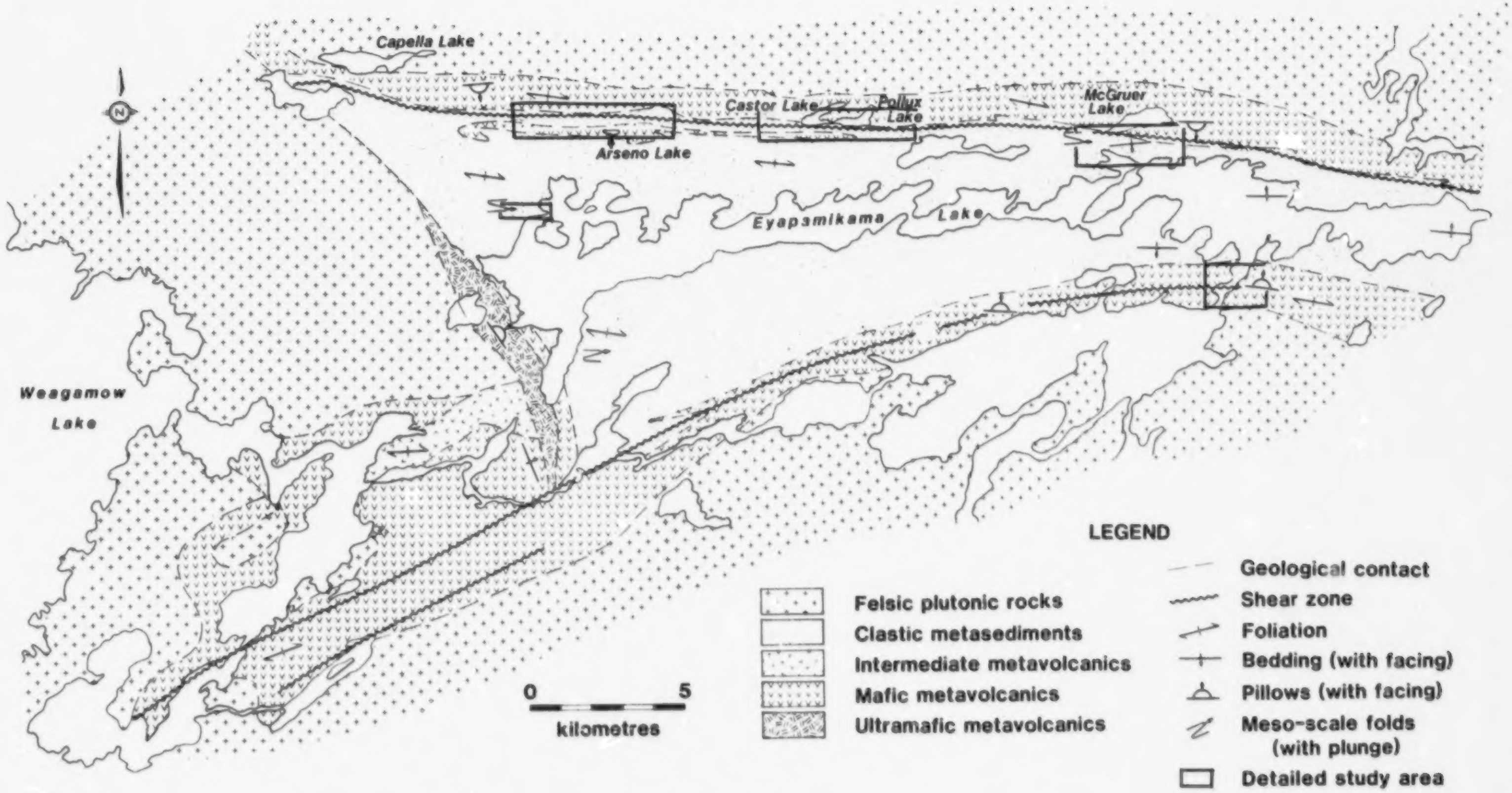

Capella Lake
Castor Lake
Pollux Lake
McGruer Lake
Arseno Lake
Eyapamikama Lake
Weagamow Lake
N
0
5
kilometres
LEGEND
Felsic plutonic rocks
Clastic metasediments
Intermediate metavolcanics
Mafic metavolcanics
Ultramafic metavolcanics
Geological contact
Shear zone
Foliation
Bedding (with facing)
Pillows (with facing)
Meso-scale folds (with plunge)
Detailed study area

Figure 076.1 General geology of the Eyapamikama Lake area.

Eyapamikama Lake region by various companies and individuals during the 1986 field season.

GENERAL GEOLOGY

Mapping by Satterly (1941) outlined the distribution of the major lithological units in the belt and established the first interpretation of the stratigraphy. Breaks *et al.* (1984, 1985) discovered new outcrop and established a more detailed stratigraphic sequence and structural interpretation. A detailed description of the lithologies and their distribution throughout the belt is provided by Breaks *et al.* (1984), Piroshco and Shields (1985), and Breaks *et al.* (in preparation).

Breaks *et al.* (1984) subdivided the supracrustal rocks into five lithological domains. Each of the domains is unique in that it possesses a distinct lithological sequence which is dominated by one lithology. The boundaries between three of the domains (Agutua Arm, Keeyask Lake, and Eyapamikama Lake) are unconformable (Piroshco and Shields 1985; Breaks *et al.* 1984) and facing directions (Bartlett *et al.* 1985) indicate that the Agutua Arm domain is the oldest, followed by the Keeyask Lake and Eyapamikama Lake domains. The original stratigraphic relationships of the other two domains (North and South Rim) to the rest of the belt are unknown because their boundaries coincide with shear zones or a paucity of outcrop.

As shown by the facing indicators on Figure 076.1, the Eyapamikama Lake Metasediments (as defined by Breaks *et al.* 1984) are folded into a series of east-plunging, open to closed folds of unknown amplitudes and wavelengths. A regional 100°-trending penetrative foliation is axial planar to these folds. Figure 076.1 also shows the North and South Rim metavolcanic domains as south- and north-facing domains, respectively (Breaks *et al.* 1984).

The regional 100° foliation is most intensely developed along or near the two major metasedimentary-metavolcanic contacts and defines the two major fault/shear zones in the region (Figure 076.1). These shear zones, which contain deformed, schistose equivalents of most of the lithologies in the region, are up to 0.5 km wide, and are host to most of the gold mineralization.

In addition to the two shear zones, the Eyapamikama Lake area exhibits a conjugate set of minor faults and a north-trending fracture cleavage. The faults include a 140°- to 160°-trending dextral set and a 020° to 050°-trending sinistral set. L:S ratios are variable in general, ranging from L equal to S, to L much greater than S.

DETAILED STUDY AREAS

Several areas were mapped in detail (Figure 076.1), using grids constructed previously by exploration companies. The McGruer Lake area (Figure 076.2) is geologically most representative of the detailed study areas and is described below. During 1986, a 2.5 by 1.0 km area on the southern shore of the lake was mapped at a scale of 1:2500. This area is well exposed and contains gold mineralization on a property referred to as the McGruer Lake Property (Assessment Files Research Office, Ontario Geological Survey, Toronto).

DESCRIPTION OF LITHOLOGIES

Mafic Volcanic Rocks

Metamorphosed mafic volcanic rocks are common on the northern and southern sides of McGruer Lake. The flows are massive in most cases, with pillowed and lesser brecciated units present along and near the southern shore of the lake (Unit 1, Figure 076.2). The rocks are dominantly composed of amphibole, the composition of which requires thin section analysis for identification.

Intermediate Volcanic Rocks

Flows and monolithic or heterolithic pyroclastic breccia units of andesitic to dacitic composition occur in lens-shaped bodies less than 100 m thick intercalated with the mafic volcanic rocks near the southern shore of McGruer Lake (Unit 2, Figure 076.2). These rocks contain up to 2 percent quartz eyes and are quartz-, sericite-, and chlorite-rich.

Chemical Sedimentary and Intercalated Rocks

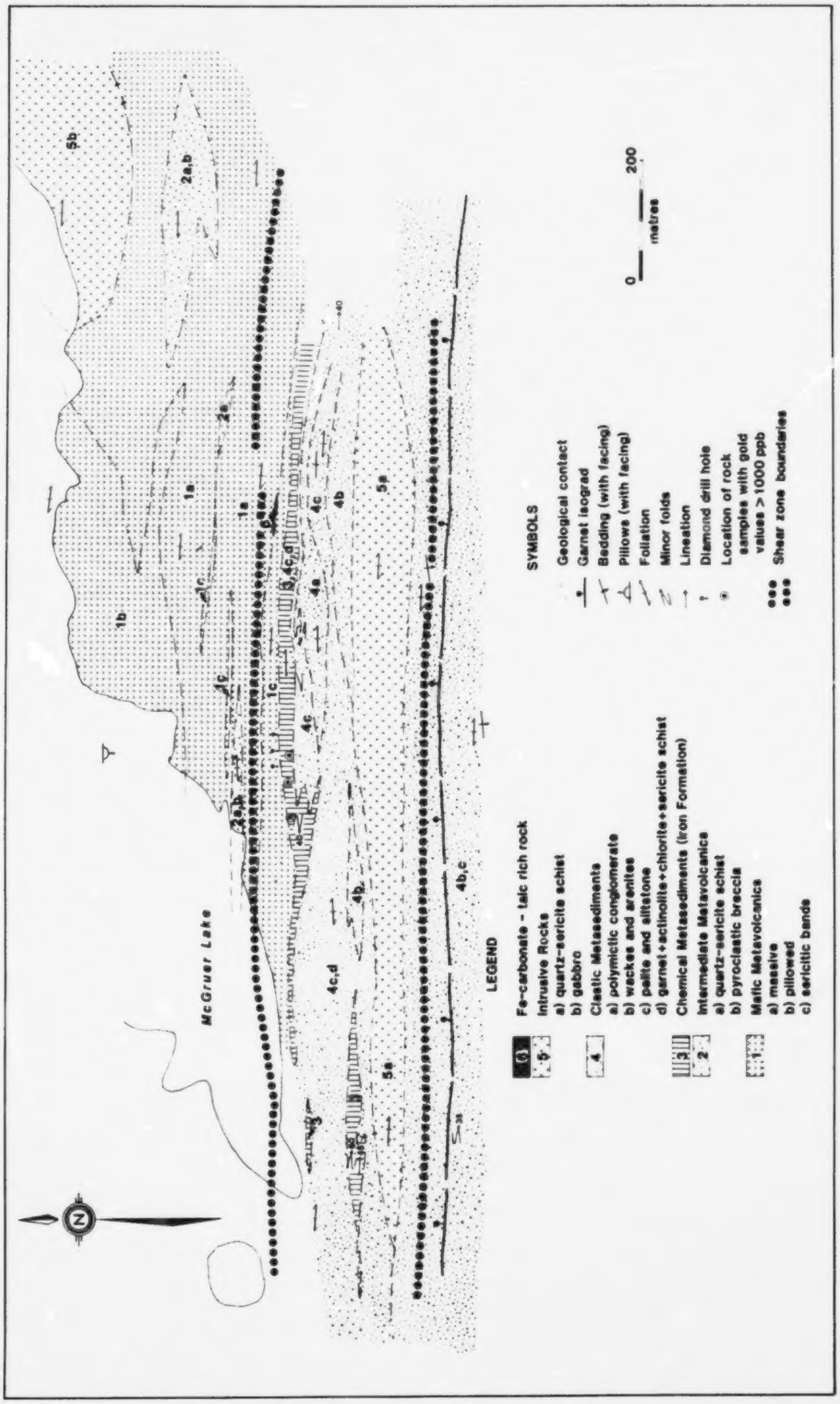
Several units of ironstone are present near the major metavolcanic-metasedimentary contact between Eyapamikama and McGruer Lakes. The ironstones include chert-grunerite iron formation (IF), lean IF, and chert-magnetite banded IF (Unit 3, Figure 076.2). The individual units are less than 15 m wide (averaging approximately 2 m) and are typically discontinuous along strike. Many of the IF units are intercalated with "ribbed" garnet+actinolite+chlorite+sericite schist (GAC schist) and finely laminated siliceous pelitic units (Unit 4d, Figure 076.2).

Conglomerate, Sandstone, Siltstone, and Mudstone

An extensive unit of clastic metasediments (Unit 4, Figure 076.2) flanks the mafic metavolcanic sequence to the south. The metamorphic grade reaches amphibolite facies at the northern side of the sequence (garnet-bearing), and decreases to lower greenschist facies to the south (chlorite-sericite-bearing). Garnets are most abundant in the GAC schist where they may be locally present as massive pods or scattered porphyroblasts, with individual garnets ranging in size from <1 mm to 1 cm.

A narrow (<50 m wide) polymictic conglomerate unit occurs near the metavolcanic/metasedimentary contact (Unit 4a Figure 076.2). It is flanked to the north by GAC schist, IF, and pelites, and to the south mainly by pelites. Most of the clasts are intensely flattened but, generally, they range from pebble to cobble size, are subangular, and consist of bleached, sericite-rich, quartz-feldspar porphyry, lean IF, and mafic metavolcanics.

Other metasediments consist of coarse- to fine-grained quartz and feldspathic arenites and wackes (Unit 4b, Figure 076.2), and thinly bedded to laminated pelites and siltstones (Unit 4c, Figure 076.2), with local graded beds up to 0.5 m thick containing basal deposits of coarse-grained quartz wacke.



McGruer Lake
N
5b
2a,b
2a
1b
1a
1c
1a
3,4c,d
4c
4b
4a
4c
5a
2a,b
4b
4c,d
4b,c
5a
0
200
metres
LEGEND
(6) Fe-carbonate - talc rich rock
5 Intrusive Rocks
a) quartz-sericite schist
b) gabbro
4 Clastic Metasediments
a) polymictic conglomerate
b) wackes and arenites
c) pelite and siltstone
d) garnet+actinolite+chlorite+sericite schist
3 Chemical Metasediments (Iron Formation)
2 Intermediate Metavolcanics
a) quartz-sericite schist
b) pyroclastic breccia
1 Mafic Metavolcanics
a) massive
b) pillowed
c) sericitic bands
SYMBOLS
Geological contact
Garnet isograd
Bedding (with facing)
Pillows (with facing)
Foliation
Minor folds
Lineation
Diamond drill hole
Location of rock samples with gold values >1000 ppb
Shear zone boundaries

Figure 076.2 General geology of the McGruer Lake area.

Metaplutonic Rocks

At least two gabbro intrusions are present in the study area (Unit 5a, Figure 076.2). They are actinolite-rich, medium to coarse grained, and variable in plagioclase contact (5 to 30 percent). Irregularly shaped quartz-sericite-rich segregations up to 1 m in size are common in the gabbro stock on the southeastern shore of McGruer Lake.

A north-trending quartz-sericite-rich dike containing up to 10 percent euhedral amphibole crosscuts the mafic metavolcanic sequence south of McGruer Lake. The dike is approximately 0.5 m wide and can be traced for approximately 15 m along strike.

A 70 m wide quartz-sericite schist unit containing less than 1 percent quartz eyes (Unit 5b, Figure 076.2) is present immediately south of the metavolcanic-metasedimentary contact. Because it contains quartz eyes and is relatively homogeneous in nature, it is taken to be of intrusive origin. This unit is characterized by the presence of local quartz-tourmaline vein stockworks.

Iron-Carbonate-Talc-Bearing Rocks

A single outcrop of iron-carbonate-talc-rich rock occurs at the contact between the GAC schist unit and mafic metavolcanics (Unit 6, Figure 076.2). The rock is massive and contains blebs of rusty weathered iron-carbonate in a bleached groundmass consisting dominantly of talc.

STRUCTURAL GEOLOGY AND METAMORPHISM

The mafic volcanic sequence south and north of McGruer Lake is interpreted to be homoclinal and south facing (Satterly 1941; and this study), based on pillow attitudes. Graded bedding within the clastic metasedimentary sequence to the south of the metavolcanics indicates that the metasediments also face dominantly south.

Folds, Foliation, and Lineations

A feature common to most of the outcrops in the area is a steeply dipping tectonic fabric striking dominantly at 100° (Figure 076.2). The fabric is defined by a pronounced penetrative schistosity and by the dimensional orientation of primary structures such as pillows, clasts in conglomerate, or fragments in pyroclastic breccias. Where a third dimension is present, a weak, linear fabric element may be present, defined by the elongation of the above mentioned primary structures, or the intersection of foliation with bedding. A preferred dimensional orientation of primary mineral grains was not observed. Both the stretching and intersection lineations plunge moderately to the east or west (Figure 076.2). Medium scale, isoclinal to closed folds are developed locally in the clastic metasedimentary sequence and the IF units, and are accompanied by an axial planar foliation of the type described above which is co-planar with the regional foliation. In some outcrops more than one planar fabric can be observed, and in the most common case, the second fabric is a north-trending fracture set. Less common is the case where two, and sometimes three, penetrative foliations can be observed. In some cases the chronology of the foliations can be determined but in others it cannot.

Shear Zones

The intensity of folds planar fabric, and lineation development is highest within an approximately 200 m wide east-trending zone coincident with the major metavolcanic-metasedimentary contact. This zone is interpreted to be a shear zone. The unit of GAC schist, and all of the IF units, are co-extensive with this structure (Figure 076.2).

Metamorphism

Two types of garnets can be identified within the metasedimentary sequence by their relationships with foliation. One type occurs as isolated subhedral porphyroblasts up to 1 cm in diameter, and as anhedral grains and grain aggregates elongate parallel to foliation. These garnets occur mainly within the GAC schist, where they locally show retrograde chlorite rims; lesser amounts occur in narrow (<3 cm wide), siliceous, rusty weathered zones within the pelitic metasediments to the south. The second type of garnet occurs as scattered euhedral porphyroblasts, generally less than 1 mm in diameter. Although garnets of the second type are less abundant overall, they show a broader distribution throughout the metasedimentary sequence and serve as the basis for the garnet isograd (Figure 076.2).

Randomly oriented, prismatic porphyroblasts of amphibole (up to 2 cm in length) commonly occur along foliation surfaces in the metavolcanics. The amphiboles show no preferred dimensional orientation within the shear zone nor do they crosscut foliation.

MINERALIZATION

Five of 28 rock samples collected from the McGruer Lake Property and analyzed for gold, yielded values of greater than 1000 ppb (Figure 076.2). These five samples were from the McGruer Lake showing (Bartlett *et al.* 1985), which was diamond-drilled in 1985 by Northern Dynasty Explorations Limited.

The McGruer Lake showing is located within the shear zone and is hosted by the tectonized unit of IF and GAC schist (Figure 076.2) described above. The showing consists of local (<1 percent), narrow (<10 cm wide), discontinuous arsenopyrite-bearing quartz veins trending parallel to subparallel to foliation, and quartz-rich pods (>1 m in size) containing massive to disseminated arsenopyrite and pyrrhotite elongate parallel/subparallel to foliation. All of the quartz-sulphide pods and veins occur within individual units of lean IF (<1.5 m wide) or within the GAC schist immediately adjacent to the lean IF. In foliated portions of the IF and the schists, the sulphide mineralization may occur as seams along foliation surfaces. The sulphide-rich zone is up to 5 m wide but there is not a direct relationship between high arsenopyrite content and high gold values. The best gold value from the showing is 5.1 g/ton across a width of 1.7 m obtained from chip sampling by Northern Dynasty Explorations Limited (Assessment Files Research Office, Ontario Geological Survey, Toronto).

The mineralized pods and veins can be traced intermittently along strike for approximately 100 m. Detailed mapping in the immediate vicinity of the showing indicates that the lithological units have a predominant west plunge and that the IF units pinch out to the west. However, the continuity of the mineralized zone at depth, and its plunge, are unknown.

Several other quartz-arsenopyrite veins and quartz-rich pods containing arsenopyrite occur within the shear zone, along strike from the showing, and in other IF units, but contain gold values less than 300 ppb.

SUMMARY

The following is a summary of geological observations and conclusions made in the McGruer Lake area:

1. A 200 m wide zone of intense deformation is coincident with a major metavolcanic-metasedimentary contact.
2. Linear fabric elements are only weakly developed within the deformation zone.
3. Metamorphism within the deformation zone and immediate surrounding rock is of amphibolite grade.
4. Chlorite schists and iron-carbonate-talc-bearing rocks present within the amphibolite grade zone indicate an event of retrograde metamorphism.
5. Gold mineralization occurs within quartz-arsenopyrite veins, and within pods of disseminated arsenopyrite hosted within a 20 m wide highly tectonized unit containing lean IF, chert-grunerite IF, and GAC schist.
6. Gold mineralization, the GAC schist, and the IF units are co-extensive with the deformation zone.

DISCUSSION

The GAC schist and IF unit mapped at McGruer Lake can be traced west of McGruer Lake to a point approximately 3 km east of Capella Lake and is host to gold mineralization at Arseno, Pollux, and Castor Lakes (Figure 076.1). The anomalously high concentration of garnets in the GAC schist relative to the surrounding lithologies suggests that the GAC schists are compositionally distinct from the surrounding rocks. This may reflect the original bulk composition of this unit or perhaps later metasomatism (hydrothermal alteration). The presence of quartz-tourmaline and quartz-sulphide veins and iron-carbonate-talc-bearing rock in the McGruer Lake area suggests the presence of a hydrothermal system. At Castor Lake, garnet-rich alteration envelopes (up to 15 cm wide) are observed to occur around quartz-tourmaline-pyrrhotite veins adjacent to gold-mineralized IF (Piroshco, in preparation).

FUTURE WORK

Future work will involve petrographic studies aimed at discriminating regional prograde metamorphic mineral assemblages from retrograde (and possibly hydrothermal) assemblages. A final report is in preparation to include the petrographic studies, all of the detailed mapping, and a regional synthesis (Piroshco, in preparation).

ACKNOWLEDGMENTS

The author would first like to thank his assistants, Carol Lormand and Jay Drew, for their dedication during the field work. He would also like to thank Ron Stewart (Geologist, Dome Exploration (Canada) Limited), Bruce Youngman (Geologist, Northern Dynasty Explorations Limited), and Eric DeKemp (Geologist, Ontario Geological Survey, Precambrian Section, Toronto) for guided tours and discussions concerning the geology of the belt.

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077. Preliminary Geochemical Studies at Opapimiskan Lake, North Caribou Lake Area, District of Kenora, Patricia Portion

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INTRODUCTION

During a six-day period in early July 1986, two small scale geochemical studies were completed in the vicinity of Opapimiskan Lake in the North Caribou Lake area, District of Kenora (Patricia Portion). One was an orientation regional geochemical survey completed in a 20 by 20 km area centred on Opapimiskan Lake and the other was two small scale humus studies completed near two mineral showings in the area. Both studies were designed to examine the feasibility of using geochemical methods, proven elsewhere in Ontario (Fortescue 1985, Fortescue and Webb 1986), in the North Caribou Lake area.

GEOLOGY

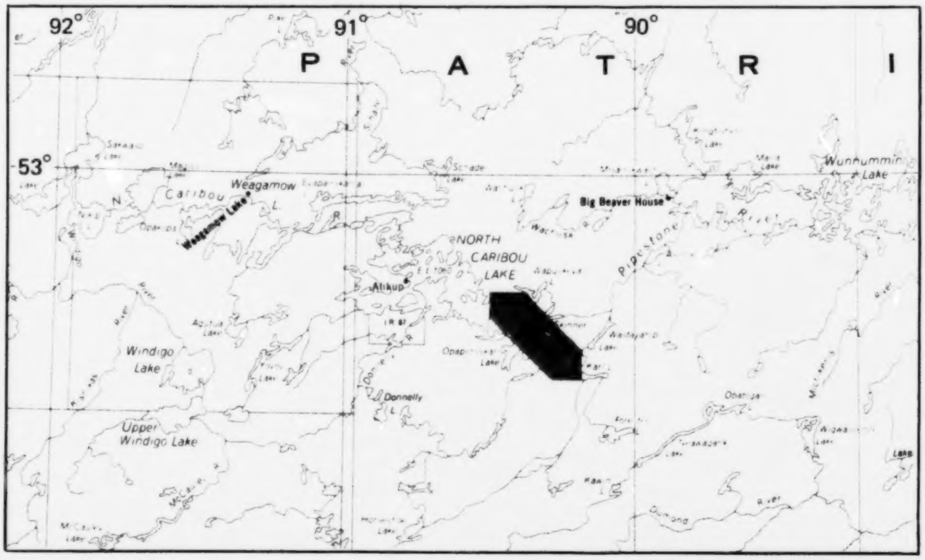
The geology of the North Caribou Lake greenstone belt area has been described by Andrews *et al.* (1981) and Breaks *et al.* (1984, 1985, and this volume). Briefly, the greenstone belt is a part of the Sachigo Subprovince which includes several relatively small, arcuate, and irregularly shaped metavolcanic and metasedimentary belts surrounded by younger granitoid rocks. Within the North Caribou Lake Belt a thick metasedimentary sequence, including conglomerates, arenites, wacke-mudstones and chemical metasedimentary rocks, is flanked on both sides by predominately mafic metavolcanic sequences. The supercrustal rocks are bounded to the north and west by migmatized rocks, mainly sedimentary in origin, and to the south by felsic intrusive rocks.

The lake sediment geochemical survey area was positioned (Figure 077.1) to include approximately one half of the area within the greenstone belt and the other half including granitic rocks on either side of the greenstone belt. Because the direction of the last ice advance during the Wisconsinan was from a northeasterly direction, a larger area of lake sediment sampling occurred to the east of the greenstone belt.

One of the humus studies was completed at the Musselwhite Property near Opapimiskan Lake, where gold mineralization is known to occur. The other humus study was completed in the vicinity of the Kenpat No.1 Deposit to the west of the northern shore of Opapimiskan Lake where gold is also known to occur.

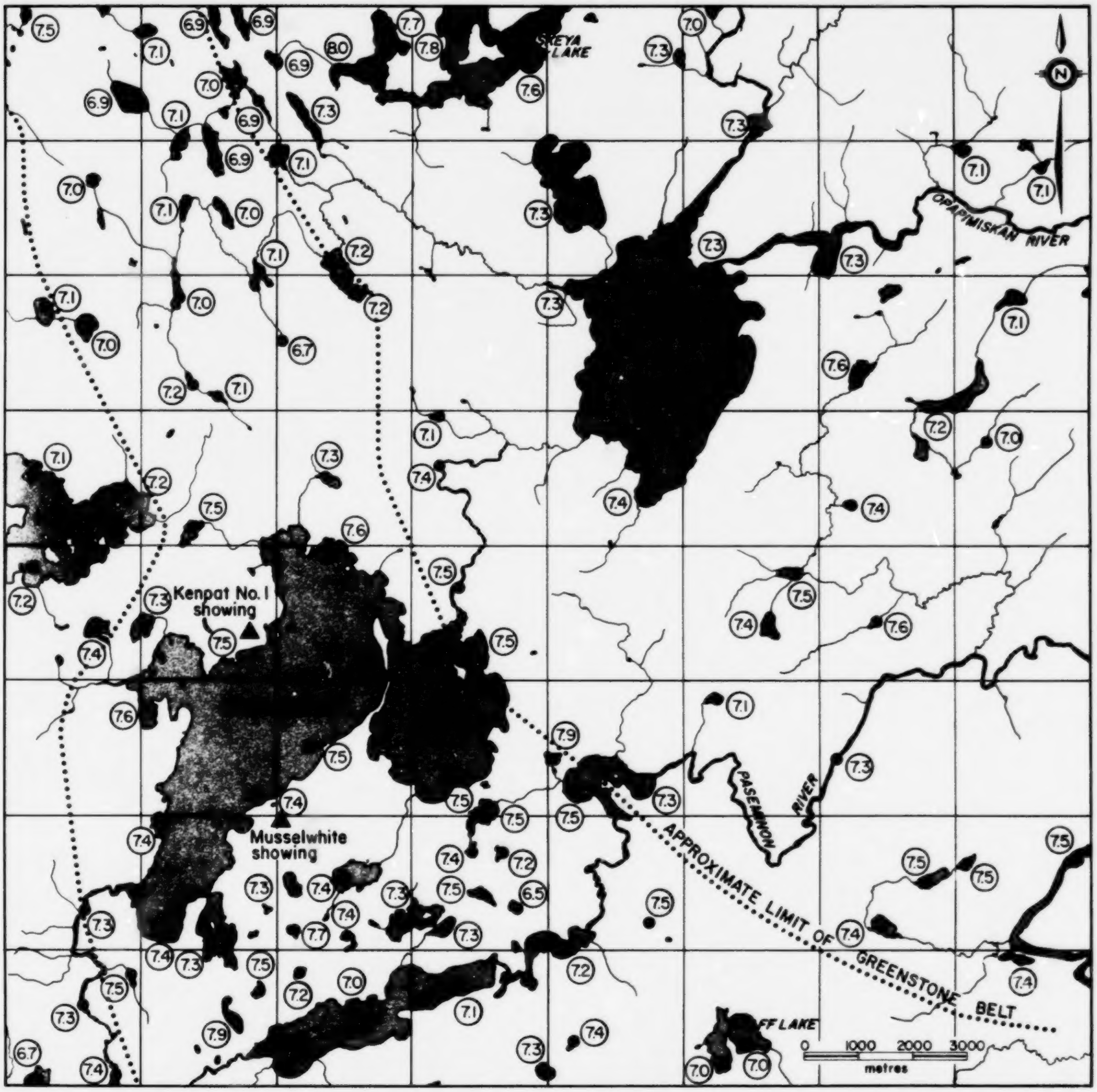
Andrews *et al.* (1981) describes the complex geology in the area where the Musselwhite Property occurs. Briefly, the property is underlain by a sequence of highly contorted rocks consisting of intercalated mafic metavolcanic flows, oxide and silicate facies of iron formation, minor tuffaceous horizons, and cherty chemical sediments. The gold is associated with grunerite-chert±magnetite banded iron formation in the North Rim Volcanics (Breaks *et al.* 1985).

At the Kenpat No.1 vein occurrence, gold is found in Pre-D^1 quartz veins in the South Rim metavolcanics (Breaks *et al.* 1985). In this area the



LOCATION MAP

Scale : 1:1 584 000 or 1 inch to 25 miles.


7.5
6.9
6.9
7.7
7.0
7.1
8.0
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SKEYA LAKE
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6.9
7.0
7.6
6.9
7.1
6.9
7.3
7.3
N
6.9
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7.1
7.1
7.0
7.3
OPAPIMISKAN RIVER
7.3
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6.7
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7.6
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7.0
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7.3
7.4
7.2
7.4
7.4
7.5
7.6
7.5
7.5
7.2
7.3
Kenpat No. I showing
7.4
7.6
7.5
7.5
7.4
7.1
7.6
7.9
7.5
PASEMINON RIVER
7.3
7.4
7.5
7.3
7.5
7.5
Musselwhite showing
7.4
APPROXIMATE LIMIT OF GREENSTONE BELT
7.5
7.4
7.2
7.5
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7.3
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6.5
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7.5
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7.1
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FF LAKE
0 1000 2000 3000
metres
6.7
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Figure 077.1. *Map of the area around Opapimiskan Lake included in the lake sediment survey, showing the pH of lakes sampled and the trace of the limits of the North Caribou Lake greenstone belt as it crosses the area.*

traverse line from which the humus samples were collected was located down a shallow slope at right angles to the strike of a large quartz vein on a south facing slope. Together, the two traverse lines represent landscape conditions typical of much of the Opapimiskan Lake area where the glacial overburden is up to only a few metres deep.

OBJECTIVES

The objectives of the study were:

1. to complete a mineral resource appraisal by regional geochemistry in a small test area at Opapimiskan Lake in order to establish the feasibility of regional geochemical surveying in the North Caribou Lake Belt
2. to discover if the sampling of humus and/or organic matter can provide reliable geochemical information regarding the location of gold showings in the North Caribou Lake Belt

METHODOLOGY

LAKE SEDIMENT AND WATER STUDY

A 20 by 20 km area was chosen for the lake sediment study, which involved the collection of 103 lake sediment and water samples. The water samples were kept cool and later tested for pH in the Geoscience Laboratories, Ontario Geological Survey, Toronto. Data obtained from this procedure are plotted on Figure 077.1. The water and lake sediment samples were collected by a crew of two using a Bell 206 helicopter mounted on floats. Owing to the favourable conditions for lake bottom sampling, using a simple gravity coring device, as many as 50 samples were collected per day. About 800 ml of sediment and 1000 ml of lake water were collected at each sample site in plastic bottles. The lakewater samples were analyzed for calcium and magnesium as well as pH, and were also used for an experimental study using the Inductively Coupled Plasma Mass Spectrometer (ICPMS) instrument installed in the Geoscience Laboratories of the Ontario Geological Survey, Toronto. The sediment material was shaken well, allowed to stand overnight, and the water decanted off. The resulting sediment material was subsampled into vials prior to being sent to a contractor for the determination of 30 elements in each sample.

ORGANIC SOIL STUDY

Humus samples were collected from the Kenpat No. 1 showing traverse line using a technique described previously (Fortescue 1985; Fortescue and Webb 1986). Briefly, this involves the collection of humus sods, from which litter and mineral matter have been removed, in large multiwalled paper sacs. The sacs are sealed in the field and brought to Toronto where they are allowed to become air dry in a warm room.

At the Musselwhite showing a different technique was used for the collection of organic matter. At this site the traverse line was located in a spruce forest on a north facing slope. The "soil" profile in this area consisted of a mat of living and decayed sphagnum humus, some 60 to 100 cm thick, lying upon glacially paved bedrock. At the interface between the organic layer and the bedrock, a layer of black "mull" organic matter (including decayed sphagnum moss and spruce needles plus ash from forest fires) was usually found. It was this layer which was sampled for geochemical analysis. The sampling procedure was similar to that used for surface humus except that the material was often very wet, or in some cases, frozen. Consequently, great care had to be taken to allow the bags to dry evenly to ensure that the samples were not spoiled.

After drying, the organic samples from both traverse lines were sent to a contractor for subsampling and chemical analysis.

PRELIMINARY RESULTS

The outline of the limits of the North Caribou Lake greenstone belt, as it crosses the lake sediment survey area, are indicated on Figure 077.1. The pH values for waters collected from the 103 sample sites are also indicated on Figure 077.1. The pH values obtained are all relatively high, and indicate that carbonate material, found in abundance in the Quaternary cover of the area (P. Finamore, Geologist, Ontario Geological Survey, Toronto, personal communication 1986), determine the pH of lake and pond waters. Indeed, some marl was present in many of the lakes sampled. Consequently, the results of the lake sediment survey will reflect the chemical composition of the bedrock only so far as the bedrock geochemistry survives the overprinting by the geochemical conditions resulting from the Quaternary deposits in the area.

SUMMARY

The feasibility of using lake sediment (and water) and organic soils as a basis for geochemical surveys in the North Caribou lake greenstone belt area is being investigated. Preliminary results from the lake water survey indicate that the lake environments are dominated by the surficial material in the area, and the success of the regional geochemical survey in the area depends upon the ability of the bedrock contribution to lake sediments to modify the effects of the Quaternary material so that elements derived from different rock types (including mineral deposits) can be identified in the geochemical data.

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078. Summary of Activities 1986, Operation Black River-Matheson (BRIM)

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INTRODUCTION

Operation Black River-Matheson (BRIM) is a multi-year, multi-disciplinary geoscience program undertaken to stimulate mineral exploration over a 40 township block along Highway 101 between Timmins (Night Hawk Lake) and the Ontario-Quebec border The mineral potential of this area is high, with some 252 showings; however, conventional mineral exploration methods are hampered by the lack of an up-to-date geological database, and thick overburden cover. The objectives of the BRIM program are:

1. to provide a comprehensive and integrated geoscience database
2. to develop a regional stratigraphic and metallogenetic framework
3. to encourage new mineral exploration strategies and development in this area

The above goals are being realized through the cooperative efforts of the Precambrian Geology, Engineering and Terrain Geology, Mineral Deposits, and Geophysics/Geochemistry Sections of the Ontario Geological Survey, and the offices of the Kirkland Lake and Timmins Resident Geologist's, Ontario Ministry of Northern Development and Mines. Specialists from each of these geological disciplines are combining their talents as part of an interdisciplinary team. In addition to achieving specific program objectives, this team approach fosters a cross-pollination of ideas which contribute to the success of the program as a whole. This integrated approach facilities cooperation and support service sharing, which makes the total program more cost effective.

The BRIM area consists of Archean age metamorphosed supracrustal and plutonic rocks of the Abitibi Greenstone Belt. The Abitibi is the largest, best preserved and most heavily mineralized Archean greenstone belt in the world, and, within Ontario, encompasses the world class mining centres of Timmins-Porcupine and Kirkland Lake-Larder Lake. Both of these camps lie adjacent to major west-trending fault zones. The Destor-Porcupine Fault Zone trends east from Timmins, passing through the BRIM area, into the Val D'Or Mining Camp of Quebec. Exploration within the BRIM portion of the fault zone has been hampered by thick overburden which covers the bedrock and limits the use of conventional mineral exploration methods.

The bedrock geology within the BRIM area is known to be complex but has not been well documented because of poor exposure. Much of its character has been extrapolated between small outcrops based on geophysical and drilling interpretations.

The bedrock surface in this area forms a broad topographic low which has been infilled with several ages of till, and glaciofluvial and lacustrine sediment forming a flat clay plain overlain by swampy organic terrain. This glacial cover is thickest (over 100 m) in the western portion and more variable to the east. Overall there is about 5 percent outcrop, with large areas totally devoid of rock exposure. This overburden cover is distributed in such a way that much of the high mineral potential ground is covered.

The BRIM program attempts to remedy this situation by undertaking baseline geological mapping, geophysical, geochemical, and mineral deposits studies to upgrade the database in a way which will encourage exploration and development. The BRIM program was initiated in 1982 with airborne geophysical surveys and Precambrian geology mapping. In each subsequent year new studies have been initiated to address specific problems and/or take advantage of new opportunities. A wide range of geological activities are currently in progress; these are described in the reports following this summary. Overviews of the BRIM program up to 1985 are given by Fortesque (1984) and Sado (1965). This program (dependent on funding) is planned to continue until 1990. Geoscientific data is being released throughout the duration of this program and will culminate with major summary reports by 1990.

PRECAMBRIAN GEOLOGY PROGRAM

The Precambrian geology program has been ongoing since 1982. It involves detailed, synoptic, and stratigraphic mapping, primarily along the Destor-Procupine Fault Zone in the western and central portions of the BRIM area. During 1986, three remote townships (Coulson, Warden and Milligan) were mapped using helicopter support. Several previously unknown bedrock outcrop areas were identified. In addition, several reinterpretations have been made regarding lithological contacts and the position of the North Branch of the Destor-Porcupine Fault in this area.

QUATERNARY GEOLOGY PROGRAM

Initiated in 1983, the Quaternary Geology program involves two main components: detailed mapping, and applied studies in aid of mineral exploration. The mapping component was completed over 1983 and 1984 and established the Quaternary geology framework. It documented the surface distribution and thickness of glacial and postglacial sediments, their stratigraphic and facies relationships, and their physical, chemical, and engineering properties.

With this framework in place, two applied studies were initiated. Starting in 1984, a till sampling program involving sonic drilling, backhoe, and hand sampling techniques got underway. This program is described by Steele *et al.* (this volume). Another shorter term project involving studies along the Munro Esker was initiated in late 1985 and was completed this year. The first year involved sampling Munro Esker sediments south of Lake Abitibi. During 1986 a detailed sedimentological study of a portion of the Munro Esker in Gauthier Township, south of the BRIM area was in progress. Esker sediments are being investigated to determine their usefulness for reconnaissance level exploration purposes in this area.

TILL SAMPLING PROGRAM

Widespread overburden cover in the BRIM area masks the bedrock and imposes severe constraints on conventional mineral exploration techniques. A major focus of BRIM has therefore been to investigate the nature of this cover and its applications to mineral exploration. Till was the prime glacial sediment selected for study because of its wide distribution, straight line transport, direct derivation from local bedrock and ease of identification in this area. Two, and possibly three, tills have been identified to date. The characteristics, transport direction, and distribution of these units are being documented. Progress to date suggests that certain till units hold promise as effective mineral exploration media.

A reconnaissance scale till sampling program was initiated in 1984 as a cooperative effort between the Geophysics/Geochemistry and the Engineering and Terrain Geology Sections. Till samples for geochemical analysis are being obtained by a combination of sonic drilling, backhoe trenching, and hand sampling methods as dictated by the terrain. This program is expected to continue until 1989.

Samples were collected during the summer and fall seasons of 1984 and 1985 along available road access. Starting in 1987 a winter drilling program is planned in remote areas to provide fill-in data. The results of this program are being released as they become available. Publications to date are listed in the by Steele *et al.* (this volume).

MINERAL DEPOSITS PROGRAM

Detailed studies on the precious metal, base metal, and industrial mineral potential of the BRIM area have been ongoing since 1984. The emphasis during 1986 has been on gold mineralization.

The long term goals of this program are to develop a metallogenetic framework, and to compile a comprehensive database with regard to stratigraphy, lithology, structure, alteration, and metamorphism within the BRIM area.

ECONOMIC GEOLOGIST PROGRAM

Complementing and contributing to the program as a whole is the economic geologist program. Initiated in 1984, and administered by the Kirkland Lake Resident Geologist's Office, the services of the economic geologist are available at the local level. The efforts of the economic geologist is directed toward providing services which promote exploration.

A major portion of 1986 field season was spent examining mineral showings. Other activities include the compilation of geological maps, mineral occurrence maps, location of diamond-drill hole and rotasonic-drill hole data. Also in progress are Geological Data Inventory Folio compilations, on a township basis, and an investigation concerning applications of Remote Sensing data to mineral exploration.

SUMMARY

Operation Black River-Matheson (BRIM) is a multi-year integrated geoscience program, initiated in 1982 and expected to continue until 1990. The purpose of the program is to stimulate mineral exploration and development in the BRIM area. Since 1983 the BRIM area has attracted unprecedented exploration interest with some 4000 new claims staked in 1984. This represents over half of the claims staked in the entire Larder Lake Mining Division. Exploration activity has remained high throughout 1985 and into 1986.

The geological situation in BRIM is not unique in Ontario. There are many areas in the province where thick overburden covers high mineral potential ground. To date, these areas are largely ignored because the technology has not been available to undertake cost effective exploration. New approaches to dealing with overburden problems are being addressed by the BRIM program using geophysical and applied geochemistry-glacial geology methods. This type of work will provide important new information to those engaged in mineral exploration in the BRIM area and can be applied in other overburden covered areas.

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079. Precambrian Geology of Coulson, Warden, and Milligan Townships, Black River-Matheson (BRIM) Area, District of Cochrane

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INTRODUCTION

The mapping of Coulson, Warden, and Milligan Townships during the 1986 field season represents the fifth year of a multi-year program of detailed mapping along the Destor-Porcupine Fault Zone in the Black River-Matheson area.

The area is bounded by Latitudes 49°37'N and 49°42'N and Longitudes 81°33'W and 80°01'W, and comprises 270 km², approximately 19 km northeast of Matheson and 55 km north of Kirkland Lake.

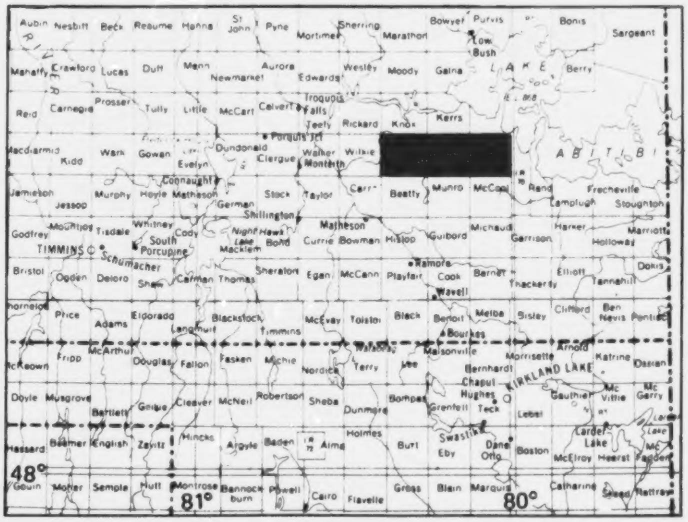
Outcrop areas in southwestern, south-central, and southeastern Coulson Township are accessed, respectively, by a prospector's trail leading north from the Maude Lake Gold Mines Limited property in northwestern Beatty Township, by a road leading to a fire lookout tower from Beatty Township along a concession road, and by an east-trending trail branching out from the fire tower road. Warden and Milligan Townships are accessible from Highway 101 via two roads situated on the north-trending Munro Esker, the former by a road to the Hedman Mine in southeastern Warden Township, and the latter through lumber roads in northwestern Milligan Township. A branch off the Hedman Mine Road in Munro Township leads to the former Potterdoal Mine and a trail trending west-northwestward from there reaches outcrop areas in southwestern Warden Township (*see* Figure 079.1). The two outcrop areas in Milligan Township can be reached directly via a second lumber road and a skidder trail which branch eastward from the main lumber road. Other outcrop areas in the three townships are best accessed by helicopter.

MINERAL EXPLORATION

Exploration information reported here was obtained from the files of the Resident Geologist, Ontario Ministry of Northern Development and Mines, Kirkland Lake.

With the exception of the large outcrop areas concentrated along the southern margins of Coulson and Warden Townships, the map area has been subjected to relatively little exploration activity due to poor access and large areas of deep overburden. Exploration has largely consisted of geophysical surveys; only a few diamond-drill holes with short bedrock intersections have been drilled. Most drilling was directed toward the discovery of gold-bearing quartz veins, but several holes along the southern Warden Township border were directed to asbestos exploration.

Despite the limited diamond drilling, two drillholes in southeastern Coulson Township (Shallow River Gold Mines Limited) and two in northwestern Milligan Township (Kennco Exploration (Canada) Limited) intersected narrow gold-bearing quartz-carbonate veins. These occurrences have not, however, been followed up by further diamond drilling. Most of the effort in recent years in the Eastford Lake area of Milligan Township has been by Bay Resources Et Services Incorporated to define placer gold deposits in the Munro Esker.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Crawford
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Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Galna
LAKE
Berry
Reid
Carnegie
Prosser
Tully
Little
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Calvert
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Teefy
Rickard
Knox
Kerrs
Macdiarmid
Kidd
Wark
Gowan
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Walker
Monteith
Wilkie
ABITIBI
Jamieson
Jessop
Murphy
Hoyle
Matheson
Connaught
German
Stock
Taylor
Carr
Beatty
Munro
McCool
Rand
Frecheville
Lamplugh
Stoughton
Godfrey
Mountjoy
Tisdale
TIMMINS
Whitney
South Porcupine
Cody
Night Hawk Lake
Shillington
Macklem
Bond
Matheson
Currie
Bowman
Hislop
Guibord
Michaud
Garrison
Harker
Marriott
Holloway
Bristol
Ogden
Deloro
Schumacher
Shaw
Carman
Thomas
Sheraton
Egan
McCann
Playfair
Ramore
Cook
Wavell
Barnet
Thackeray
Elliott
Tannahill
Dokis
Thorneloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Bourkes
Melba
Bisley
Clifford
Ben Nevis
Pontiac
McKeown
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Douglas
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Fasken
Michie
Nordica
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Arnold
Katrine
Dasserat
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KIRKLAND LAKE
Doyle
Musgrove
Bartlett
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McNeil
Robertson
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Dunmore
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Gauthier
Mc Vittie
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Hassard
Beemer
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
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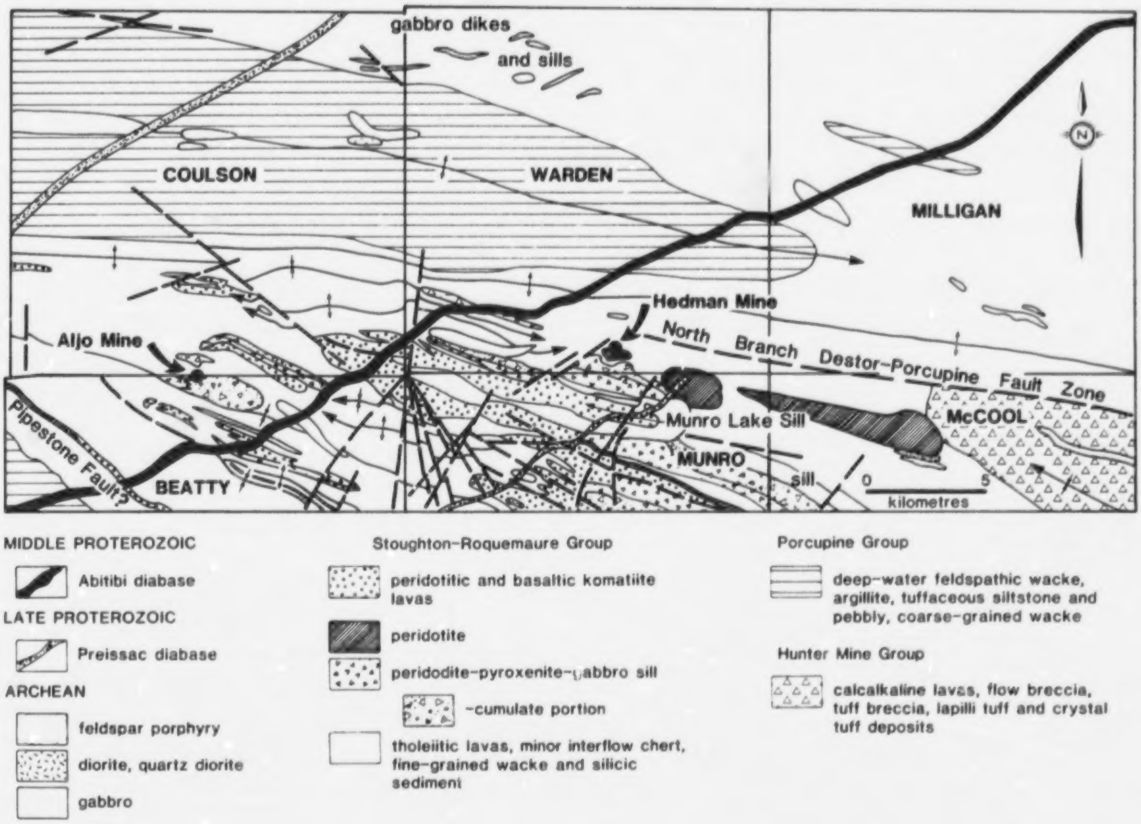
Hearst
McFadden
48°
Gouin
Mottier
Semple
Hutt
Montrose
Bannockburn
Powell
81°
Cairo
Flavelle
Gross
Blain
Marquis
80°
Catharine
Skead
Rattray

LOCATION MAP   Scale : 1 : 1 584 000 or 1 inch to 25 miles


gabbro dikes
and sills
COULSON
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North Branch Destor-Porcupine Fault Zone
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MIDDLE PROTEROZOIC
Abitibi diabase
LATE PROTEROZOIC
Preissac diabase
ARCHEAN
feldspar porphyry
diorite, quartz diorite
gabbro
Stoughton-Roquemaure Group
peridotitic and basaltic komatiite lavas
peridotite
peridodite-pyroxenite-gabbro sill
-cumulate portion
tholeiitic lavas, minor interflow chert, fine-grained wacke and silicic sediment
Porcupine Group
deep-water feldspathic wacke, argillite, tuffaceous siltstone and pebbly, coarse-grained wacke
Hunter Mine Group
calcalkaline lavas, flow breccia, tuff breccia, lapilli tuff and crystal tuff deposits

Figure 079.1. *Generalized Geology of Coulson, Warden, and Milligan Townships.*

The only gold produced from the map area was mined at the Aljo Property straddling the central Beatty/Coulson Township border. By 1940 this prospect, developed initially by Hattie Gold Mines Limited and later by Devon Gold Mines Limited, consisted of a 575 ft (175 m) shaft with five levels and 9928 ft (3008 m) of lateral development, a second 450 ft (121 m) shaft with a 300 ft (91 m) drift, and a 100 ton per day mill. The grade was estimated at 0.26 ounces gold per ton but only 2333 tons were milled in the only year of production (Satterly *et al.* 1947). From this, 42 ounces of gold and five ounces of silver were produced.

The only operating mine in the area is the Hedman Mine in southern Warden Township. This open pit operation produces a serpentine filler product referred to as "Hedmanite" which essentially consists of 86 percent lizardite and 14 percent chrysotile (Malczac 1984). At present, production at the mine is limited.

REGIONAL SETTING

Units within this map area are related, for purposes of regional correlation, to the stratigraphic scheme developed in the Kirkland Lake area by Jensen and Langford (1983), involving three successively younger volcanic cycles. In that scheme, the Hunter Mine Group represents the calc-alkalic top of the second cycle in this area, disconformably overlain by the Stoughton-Roquemaure Group which is the mafic-ultramafic base of a third cycle, and the Porcupine Group sedimentary rocks, which are equivalent to volcanic rocks of both cycles.

In a large scale sense, the map area is on the northern flank of the east-trending Blake River Synclinorium, a major structure which involves only rocks of the third volcanic cycle.

GENERAL GEOLOGY

Calc-alkalic volcanic rocks of the Hunter Mine Group occur in northeastern McCool Township marking the western extent of a calc-alkalic volcanic pile centred 15 km away in Rand Township. The only occurrence of Hunter Mine Group rocks within the map area is found in southeastern Warden Township where a few small outcrops expose massive flows of feldsparphyric rhyolite. It is suspected that calc-alkalic flows do occur unexposed within southern Warden and Coulson Townships, but only as thin, discontinuous sequences isolated within the surrounding Stoughton-Roquemaure Group succession. Two such felsic flow sequences occur within the Stoughton-Roquemaure Group in Beatty and Munro Townships, immediately to the south of the project area. They are interpreted to represent late Hunter Mine Group volcanic rocks (Johnstone and Trowell 1984) inferring that there was some degree of overlap between the second and third volcanic cycles.

Although poorly exposed, sedimentary assemblages likely underlie much of central Coulson and Warden Townships. The rocks are predominantly distal facies argillites and fine-grained feldspathic wackes, similar to sedimentary rocks of the Porcupine Group exposed in Munro and Beatty Townships. The Porcupine Group sedimentary rocks are time equivalent to both Stoughton-Roquemaure and Hunter Mine Group volcanic rocks and are interpreted to consist of detritus shed from the erosion of Hunter Mine Group volcanic piles (Jensen and Langford 1983). These packages of sedimentary strata, enclosed within the Stoughton-Roquemaure Group in this area, likely represent Porcupine Group deposits separated both spatially and stratigraphically from the main belt of Porcupine Group sedimentary rocks, which extends west from the west-central BRIM region to the Timmins area.

The sedimentary assemblage exposed in southern Coulson Township contains a few beds of massive coarse and/or pebbly wacke. These may represent mass-flow deposits caused by periodic slumping from the edge of graben structures formed along the flanks of the older calc-alkalic (Hunter Mine Group) volcanic complexes, at a point where they were onlapped by younger (Stoughton-Roquemaure Group) mafic-ultramafic flows (Jensen and Langford 1983).

Within the project area, mafic and ultramafic volcanic rocks of the Stoughton-Roquemaure Group are dominant in terms of areal distribution. In this area, this group comprises mostly magnesium-rich tholeiitic basalts with iron-rich tholeiites, basaltic komatiites, and peridotitic komatiites being less common. In particular, magnesium-rich tholeiitic basalts dominate the stratigraphy in southwestern Coulson Township and occupy a stratigraphic position which corresponds with a thick sequence of komatiitic flows in south-central Coulson, southwestern Warden, and northern Munro Townships. Unlike the Munro sequence, the Coulson komatiites, within this belt of magnesium-rich flows, are dominantly of the basaltic variety. Basaltic komatiites, iron and magnesian-tholeiites, all commonly form both pillowed and massive flows. Distinctive plagioclase-phyric flows of magnesium-rich tholeiite are common in south-central, southwestern, and northwestern Coulson Township.

Mafic intrusive rocks are generally more resistant to weathering and hence much better exposed than the supracrustal strata of the region; indeed in many areas, the supracrustal rocks are preserved only because of their proximity to gabbroic intrusions. Such intrusions, including dikes following east-trending faults, are relatively numerous in this part of the Abitibi Belt, and are concentrated in two bands across the southern and northern parts of Coulson and Warden Township.

The northern band consists of at least four sills, each about 100 m thick, and a few discordant gabbro bodies of uncertain dimensions. These intrude a well-exposed sequence of pillowed and massive magnesium and iron-rich tholeiites.

The southern band is characterized by layered sills which intrude tholeiitic and komatiitic flows and interflow sedimentary rocks. In southern Warden and northern Munro Township, there is a thick sill complex about 800 m thick. It consists of a cumulate zone of alternating peridotite, hornblende peridotite, and clinopyroxene layers, an overlying gabbro unit and an upper leucogabbro layer.

This layered sill can be traced for many kilometres southeastward into McCool Township back around the southern limb of a large syncline, the McCool Hill Syncline (Johnstone and Trowell 1985), and back to the centre of Munro Township.

Smaller layered sills, comprised of similar rock types, are exposed in McCool Township, Indian Reservation 70, and Garrison Township farther to the southeast, and in south-central Coulson Township. It is possible that these intrusions, and similar sills exposed further west, for example those in Dundonald Township, were comagmatic and intruded along a single east-west fissure system related to the development of the Destor-Porcupine Fault Zone.

Also associated with this belt of layered mafic intrusions are peridotite/pyroxenite, peridotite, and dunite bodies. A string of small discordant dunite bodies, including one hosting the Hedman Mine deposit, trends west from the Hedman Mine area to the western edge of Warden Township. In addition an approximately 90 m thick perioditite pyroxenite sill is exposed in the Aljo Mine area in south-central Coulson Township. A few small outcrops in east-central Coulson Township expose a partially carbonatized and silicified plagioclase-phyric rock; it is uncertain whether these were originally of intermediate or mafic composition and whether they represent synvolcanic sills or later fault-related intrusions.

Diabase dikes, belonging to three different dike swarms, intrude the supracrustal strata. These include a large number of north-trending Matachewan quartz diabase dikes (2630 Ma), two northeast-trending Preissac quartz diabase dikes (2150 Ma), and an east-northeast-trending Abitibi olivine diabase dike (1150 Ma).

METAMORPHISM

The supracrustal rocks have been affected by regional metamorphism of subgreenschist rank. This prehnite-pumpellyite facies metamorphism allows for well preserved primary mineral textures. Substantial zones of carbonatization and silicification occur along faults in northeastern, east-central, southwestern, and south-central Coulson Township and in northwestern and southwestern Warden Township.

RECENT AND PLEISTOCENE GEOLOGY

The Pleistocene cover in the Black River-Matheson area can be over 100 m thick in places, particularly above erosional valleys corresponding to the location of Porcupine Group sedimentary rocks. The deposits consist of: Wisconsinan silty sand tills; ice-contact stratified deposits of sand, gravel, and locally, cobbles, boulders and silt; reworked ice-contact deposits; and lacustrine deposits of both shallow water sand and gravel, and younger deep-water silt and clay. This succession of deposits represents ice retreat, the inundation of the area and progressive deepening of glacial Lakes Ojibway and Barlow (Vagners 1983). Ice-flow direction was toward the south-southeast at approximately 165° (Vagners 1983). The most common deposits exposed in the project area are the lacustrine silts and clays and ice-contact stratified deposits in the form of the Munro Esker and its associated kames. The Munro Esker Complex, straddling the Milligan-Warden Township border, is characterized by eolian dunes formed after lake waters had receeded.

Upon emergence of the land, accumulations of organic matter, in the form of peat, began to develop in swamps and on stream flood plains.

STRUCTURAL GEOLOGY

The rocks of the map area constitute a portion of an east- to southeast-trending fold belt, characterized by upright to slightly overturned tight or isoclinal folds arranged in an *en echelon* pattern. Despite this tight folding, most of the rocks in the region lack evidence of penetrative deformation. Typically, pillows are well preserved, and provide abundant reliable stratigraphic top indicators.

For the most part, subvertical axial plane cleavages are weakly developed in the hinge areas of folds unless accentuated, as is common for the area's anticlines, by normal fault development.

A second set of northeast-oriented open folds, pre-dating the intrusion of the Matachewan diabase dikes, is superimposed upon the east-west folds.

The belt of Porcupine Group sedimentary rocks in the centre of the area forms the core of an east-trending northerly inclined syncline; the axial trace of this structure is only vaguely defined. It appears that the fold persists throughout the map area and westward into Wilkie Township. The axial trace of a second major syncline, the McCool Hill Syncline (Johnstone and Trowell 1985), is situated in southwestern Coulson Township. The hinge area of the anticline separating these two synclines is not well exposed but there is a zone characterized by carbonatized basalt and parallel-trending gabbro dikes, subvertical shears, and minor isoclinal folds. This sheared anticline may, in fact, represent the western extension of the North Branch of the Destor-Porcupine Fault Zone (after the usage of Jensen and Langford 1983). This normal fault splays off the main Destor-Porcupine Fault Zone in the area of the Ghost Range south of Lake Abitibi, and extends northwestward for at least 20 km into the southern part of the project area. The Destor-Porcupine Fault Zone is a profound, long, active regional "break"; the North Branch splay was likely an early growth fault (Jensen and Langford 1983).

East-trending shear zones are common in the central portions of the map area and many of the gabbro bodies undoubtably intrude some of these fissile zones. One identifiable fault zone is exposed at a point along the Shallow River bordering the northern edge of the sedimentary rocks. Slickenslides, where identifiable in the silicified rocks found here, indicate a strike-slip motion of the fault.

ECONOMIC GEOLOGY

GOLD

Gold occurs in both the native state and combined with pyrite in quartz and quartz-carbonate veins and stringers in the rocks of the Black River-Matheson area. Auriferous quartz veins are not associated with a particular host rock, but are found in ultramafic, mafic, and felsic volcanic rocks, interflow sedimentary rocks, Porcupine Group sedimentary rocks, and in various felsic intrusions. The most significant gold deposits, both in the western Black River-Matheson area and the Timmins area (Hodgson 1983), do, however, share three common characteristics; a) carbonatization of the country rock, b) association with felsic porphyritic intrusive and/or extrusive rocks, and c) proximity to the Destor-Porcupine Fault Zone.

Destor-Porcupine Fault Zone

The Destor-Porcupine Fault Zone is narrow and its location reasonably well defined in the Porcupine Camp, but in the BRIM region its precise location and width is unknown for most of its length; branch faults of uncertain length splay off it toward the west. Considering the long history of activity (Jensen and Langford 1983) of the Destor-Porcupine Fault Zone, the area between the northern and southern branches of the structure likely contains several generations of subparallel, normal faults. Research should be focused toward the problems of identifying and tracing those faults and related fracture systems that were active at the time of gold mineralization.

Felsic Intrusions

At present, research is also being directed toward the dating of various felsic porphyritic intrusions (Marmont 1983) which will help identify specific suites of felsic porphyritic rocks that host or accompany gold mineralization. The link between porphyritic intrusions and gold mineralization is not clear in all cases. Depending on the deposit, the relationship may be:

1. direct, that is the particular felsic magma was either the source of the gold, or heat from the intrusion drove mineralizing fluids
2. indirect, wherein the intrusions followed the emplacement of the auriferous veins, preferentially intruding open fractures that had served as conduits for the mineralizing fluids

In the latter case the particular series of dikes once defined, could identify by their presence a specific generation of faults and fractures which were available to fluid at the time of mineralization. The presence of these intrusions should be considered to be an important exploration criterion.

Suggestions for Gold Exploration

With the above factors in mind, quartz-carbonate veins and stringers in a number of carbonatized faults and shear zones were sampled during the present survey for gold and silver analysis. Four such sites in Coulson Township, each of which warrants further exploration, include:

1. the southwestern corner of the township, because of its proximity to a proven gold-bearing structure, the Pipestone Fault, which is related to the Destor-Porcupine Fault system
2. a waterfall on the Shallow River at the southeastern edge of the township, where diamond drilling has intersected feldspar porphyry dikes and auriferous quartz-carbonate veins close to the projected extension of the Destor-Porcupine Fault Zone's northern branch
3. a feldspar porphyry body which intrudes sedimentary rock in the northeastern quarter of the township
4. a fault zone along the contact between feldspar porphyritic andesite and sedimentary rocks at the northern edge of the township along the Shallow River, a site where gold has already been reported (Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Kirkland Lake)

Pyritiferous siliceous siltstone, exposed at the central Warden/Munro Township border and in south-central Milligan Township, should also be investigated because similar white-weathering interflow sedimentary rocks, exposed in the Kinojevis Group of Harker and Holloway Townships, have been found to carry anomalous gold values.

The most promising exploration targets in this area are believed to be major east-trending faults. These commonly occur along zones of high rock competency contrast, such as between the sedimentary and volcanic sequences in northern Coulson Township, and along the margins of the gabbro sills which intrude those sedimentary rocks.

COPPER AND ZINC

The existence of former copper and zinc mines in northern Munro Township establishes the potential for base metal deposits in the area. These deposits are contained within units of cherty interflow sedimentary rocks and flow breccia within a succession of komatiitic and tholeiitic lavas in the case of the Potter Mine (Coad, 1976) and, in the case of the Potterdoal Mine, mineralization is at the top of a succession of tholeiitic lava flows.

Both deposits were located a short distance stratigraphically above the Munro Lake Sill. Similar deposits may occur immediately above the sill in southwestern Warden Township but more promising exploration areas are probably north-central McCool, southwestern Milligan, and southeastern Warden Townships, where it is most likely that a sedimentary apron deposit flanks the edge of the Hunter Mine Group volcanic pile.

NICKEL

The layered sills and ultramafic intrusions of southern Warden and Coulson Townships hold some potential for nickel sulphide mineralization. A nickel sulphide deposit occurs in a related ultramafic intrusive complex 37 km to the west (Alexo Deposit) and minor quantities of massive and disseminated pentlandite do occur in some of the ultramafic rocks in Warden and Munro Townships, but until now, no significant showings have been found.

ASBESTOS

The Hedman Asbestos Mine in south-central Warden Township is capable of rapid expansion of production, if demand should improve. More deposits of this type, within serpentinized dunite bodies, are probable both east and west of the mine.

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080. Reconnaissance Till Sampling Program, Matheson-Lake Abitibi Area, District of Cochrane

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INTRODUCTION

A reconnaissance scale overburden sampling program in the Black River-Matheson (BRIM) area began in 1984 and is expected to be completed in 1989. The program is a combined effort of the Geophysics/Geochemistry and the Engineering and Terrain Geology Sections of the Ontario Geological Survey. The sampling, largely completed by deep overburden drilling, is of particular value in the area due to the extensive and thick drift cover. In the study area there is approximately 5 percent outcrop, with occasional townships totally devoid of outcrop. The results of the BRIM program will establish a regional Quaternary (glacial) stratigraphy and provide a till geochemistry database. The data and interpretations produced by the program are of practical importance for exploration.

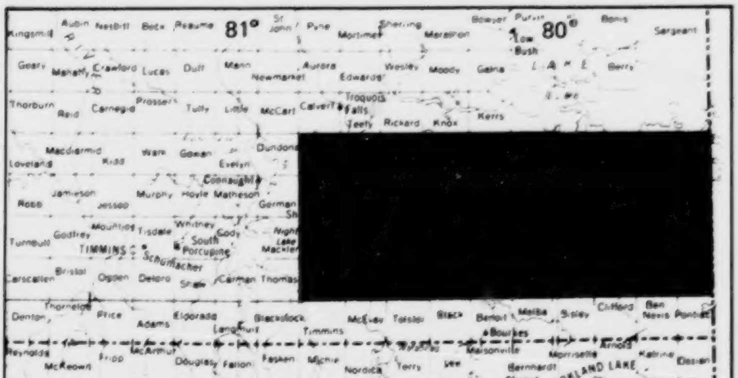
QUATERNARY HISTORY

The study area was deglaciated approximately 10 000 years before present. The most recent glacial advance was towards 170° and deposited the Matheson till (informal name). Matheson till can be correlated across the Abitibi Greenstone Belt from Quebec to Timmins. During the later stages of ice cover, esker systems which trend parallel to the ice flow direction were established. As the ice front wasted away to the north, it was fronted by glacial Lakes Barlow and Ojibway. The existence of these bodies of water resulted in the deposition of thick and extensive glaciolacustrine clay deposits which mask most of the bedrock and flank or lap onto the eskers.

Overburden drilling in the Matheson area has indicated the presence of at least one, and possibly two, glacial packages under the Matheson till. These older deposits are scattered and usually occur in bedrock depressions oriented perpendicular to the most recent direction of glaciation (170°). These lower glacial packages generally consist of varved clays and/or glaciofluvial sands overlying till. In the study area the earliest discernible ice advance was toward 240°.

TILL SAMPLING

A requirement of the till sampling program was to provide as even a distribution of sample sites over the study area as possible. It was also required that at each site a complete drift sequence from the ground surface to bedrock be available for descrip-



LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

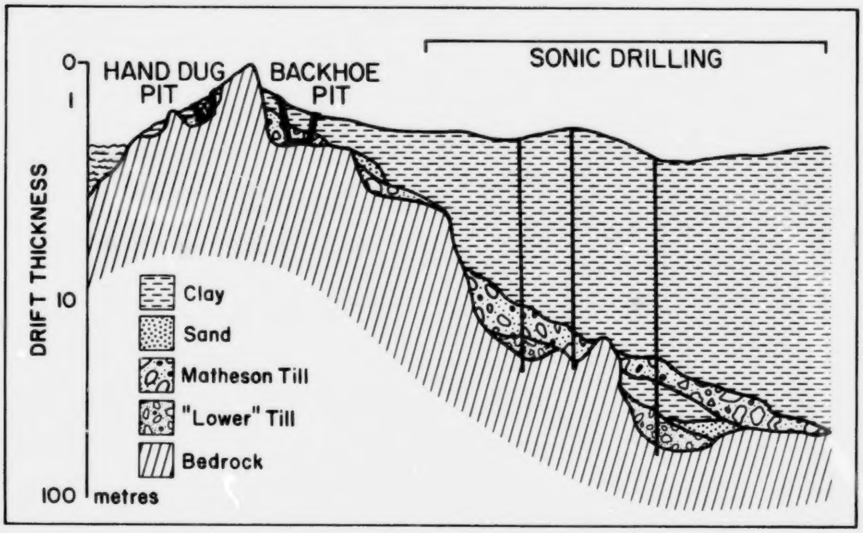


Figure 080.1. *Sampling methods in various exploration environments.*

tion and sampling. To achieve these requirements, three sampling methods were used: sonic drilling, backhoe trenching, and hand dug pits. Sampling environments appropriate for each of these methods are outlined on Figure 080.1.

In areas of shallow drift, or when till is at surface, trenching was used to search for and sample the till. When these areas were near roads or cleared land, backhoes were used to dig trenches up to 4 m deep. Backhoeing is a fast, economical method for collecting fresh, undisturbed bulk till samples. When these areas were accessible only by boat, float plane, or trail, pits up to 1.5 m deep, were dug by hand.

In areas of thick drift, sonic drilling was chosen because it furnishes a continuous, relatively undisturbed, 88 mm diameter core from all formations, including the bedrock. The core provides a detailed stratigraphic record for the interpretation of depositional environments and large, complete samples for geochemical analyses. Detailed logs and samples collected on the basis of stratigraphy, are required to interpret the complex Quaternary stratigraphy encountered in some basins within the study area. Some examples of stratigraphic relationships encountered in the BRIM area are illustrated on Figure 080.1.

PREVIOUS SAMPLING

In the period July 1984, to September 1985, two backhoe trenching and two sonic drilling programs were carried out in the study area. The 1984 field work was carried out in the western 16 townships of the BRIM area. In 1985 work was concentrated in the central and eastern parts of the area.

To date 241 till samples have been collected from 312 sites by backhoe trenching. At each site, if till was not found in the first trench, up to two additional trenches were dug. Backhoe site selection, equipment, and sampling results have been described in previous field season summaries (Baker *et al.* 1984, 1985). Data publications are listed in Table 080.1. Site descriptions and geochemistry for the 1985 backhoe samples are expected to be published early in 1987.

A sonic dill program, carried out in the fall of 1984, completed 42 holes in the western BRIM area. This program utilized a skid-mounted drill, and the sites were positioned beside all weather roads. In the late summer of 1985, sonic drilling took place along road access in the 20 townships at the eastern end of the BRIM area. In addition, fill-in drilling was completed in the northwestern and southwestern corners of the 1984 area. This 60-hole program used a truck mounted drill system. Drilling methodology and operations are described in Baker *et al.* (1985) and Averill *et al.* (1986). Publications containing data from these programs are listed in Table 080.1. Geochemical/Stratigraphic datasheets for the 1985 drillholes are expected to be published in late 1986 and early 1987.

During the summer of 1986, drill core from both sonic drilling programs was sorted. Core for holes drilled in the Larder Lake Mining Division (all of the study area except for the 4 westernmost townships) is stored at the Kirkland Lake Drill Core Library. Core for holes drilled in the Porcupine Mining Division (holes drilled in Sheraton, Stock, Bond, and Clergue Townships) is stored at the Timmins Drill Core Library. All bedrock core and the 1984 overburden core is available for public inspection. The 1985 overburden drill core will become available upon public release of the geochemical data for that particular hole.

SAMPLING IN 1986

During the summer of 1986, eight days were spent hand sampling in areas inaccessible to either a backhoe or drill. A week was spent checking for, and sampling, till exposures along the shoreline of Lake Abitibi. One day was spent at both McDiarmid Lake (Marriot Township) and Webster Lake (Tannahill Township) checking surficial geology along the lakeshores and sampling till.

TABLE 080.1: DATA PUBLICATIONS.

1) 1984 Sonic Drill Holes Geochemical/Stratigraphic Datasheets

Hole #		Township	OGS Map #
84-01		CARR	80761
84-02		CARR	80762
84-03		BEATTY	80763
84-04		BEATTY	80764
84-05		CARR	80765
84-06		BEATTY	80766
84-07		CARR	80767
84-08	(and 84-11)	BEATTY	80768
84-09		HISLOP	80769
84-10		BEATTY	80770
84-11	(and 84-08)	BEATTY	80768
84-12		BEATTY	80771
84-13		HISLOP	80772
84-14	(and 84-16)	HISLOP	80773
84-15		PLAYFAIR	80774
84-16	(and 84-14)	PLAYFAIR	80773
84-17		HISLOP	80775
84-18	(and 84-19)	BOWMAN	80776
84-19	(and 84-18)	McCANN	80776
84-20	(and 84-21)	BOWMAN	80777
84-21	(and 84-20)	CARR	80777
84-22		TAYLOR	80778
84-23		CARR	80779
84-24		BOWMAN	80759
84-25		CURRIE	80780
84-26		CURRIE	80781
84-27		TAYLOR	80782
84-28		CURRIE	80760
84-29		CURRIE	80783
84-30	(and 84-34)	STOCK	80784
84-31		BOND	80785
84-32		STOCK	80786
84-33		STOCK	80787
84-34	(and 84-30)	TAYLOR	80784
84-35		STOCK	80788
84-36		STOCK	80789
84-37		STOCK	80790
84-38	(and 84-39)	TAYLOR	80791
84-39	(and 84-38)	TAYLOR	80791
84-40	(and 84-41, 42)	TAYLOR	80792
84-41	(and 84-40, 42)	CARR	80792
84-42	(and 84-40, 41)	TAYLOR	80792

Thirteen sites were described and sampled along the Lake Abitibi shore. When encountered, till usually was a discontinuous, 0.2 to 0.5 m thick layer immediately above the modern maximum beach/wave wash limit of the lake. Till was, almost without exception, overlain by 2 to 5 m of varved clay forming shore bluffs. Till often onlaps bedrock and fills bedrock depressions. The best locations for finding till are in bays between bedrock controlled headlands. The till sampled generally had a massive, loose, gritty silty sand matrix with a clast (+10 mesh) content of 3 to 15 percent. Typically, clast angularity ranged from angular to subrounded. Many of the pebble-sized clasts were striated. Except for one site, the till was interpreted to have been deposited subglacially by either the lodgement or melt-out processes.

At McDiarmid Lake, six exposures of surficial sediments were checked. Weakly oxidized till was encountered and sampled at two of these sites.

TABLE 080.1: DATA PUBLICATIONS cont'd.

2) 1984 Backhoe Till Samples Geochemical Datasheets

Township	OGS Map #
Stock, Taylor, Carr, Currie, Bowman, Sheraton Twps.	80793
Coulson, Beatty, Hislop Twps.	80794
Clergue, Walker, Wilkie Twps.	80795
Playfair, McCann Twps.	80796

3) Gold Grain Datasheets 1984 & 1985

Title	OGS Map #
Gold Grains in Sonic Drill Samples 1984	P2736
Gold Grains in Sonic Drill Samples 1985	P2958
Gold Grains in Backhoe Till Samples 1984-85	P2983

4) Bedrock from Sonic Drilling Program, Description and Map

Year	OGS Map #
1984	P2848
1985	P2986

5) Quaternary Geology Maps in BRIM Area

Name	NTS Reference	OGS Map #
Porquis Junction	42A/10	P2949
Watabeag River	42A/7	P2950
Matheson	42A/9	P2735
Ramore	42A/8	P2381
Lightening River	32D/12	P2734
Magusi River	32D/5	P2483

Striae measured around the lakeshore indicated the last ice advance through the area moved toward 156° to 166°. At Webster Lake, no natural exposures of surficial sediments were seen. Two hand-dug pits along the southeastern shore of the lake resulted in the collection of one till sample. The till sampled at these lakes was similar in texture, structure, clast content, and genesis to that encountered along Lake Abitibi.

SAMPLE ANALYSIS

Till samples collected by drill, backhoe, and hand as part of the program were processed in the same manner. For each sample interval, a 7 to 10 kg bulk sample and two 250 g samples were collected. For intervals with numerous pebble sized clasts, clasts were bagged for later determination of pebble angularity and lithology. The bulk till samples were sent for heavy mineral separation. Processing steps were outlined on a flow chart presented in Baker *et al.* (1985). Samples with gold grains visible on the shaker table were further refined by a secondary panning procedure of the heavy mineral concentrates, to obtain the exact number, shape, and size of gold grains. The presence of significant numbers of delicate and irregular gold grains in till, especially in several adjacent vertical drill samples, is of exploration interest, as it is likely the source is nearby in the "up ice" direction. Mineralogical study of the heavy mineral concentrates consisted of a 100 grain point count, plus a scan for indicator and accessory minerals. The entire non-magnetic heavy mineral (>3.3 S.G.) concentrate ("H" fraction) was analyzed for gold and other trace elements by Instrument Neutron Activation Analysis (INAA). The concentrate was then split, with half (a minimum of 10 g) analyzed for a suite of trace elements and the remainder stored for future reference. Selected non-magnetic and magnetic heavy mineral concentrates were analyzed for platinum and paladium. From one of the 250 g samples the -250 mesh material ("G" fraction) and -10 mesh material ("T" fraction) were obtained. These fractions were analyzed for the same suite of trace elements as the "H" fraction, with the exception of tellurium. To determine the extent, nature and variability of the bedrock in the glacial sediments, whole rock geochemical analyses were done on the "T" fraction. The second 250 g sample was submitted for till matrix size (texture) analysis and carbonate content determination. By combining geochemical, mineralogical, texture, carbonate, and clast data, units can often be separated within a drillhole or correlated between sampling sites.

FUTURE SAMPLING

Over the next two years (1987 and 1988) three types of sampling are anticipated to complete the collection of till samples across the BRIM area. The sampling types are:

1. winter sonic drilling in areas of thick drift which lack all weather roads
2. detailed hand sampling along the Lake Abitibi shoreline and on selected remote lakes and rivers
3. backhoe trenching along newly developed logging roads and roads which were previously blocked by washouts

A winter drilling program is planned for the winter of 1987 and a similar program is anticipated for the winter of 1988. These two programs should result in an even distribution of sonic-drill holes in areas of thick drift across the study area. The plan is to use sonic drills, so that past and future drilling results can be compared and correlated.

GOLD IN TILL FRACTIONS

In an attempt to evaluate the usefulness of the "fine" fraction of the till to gold exploration in the Matheson area the Ontario Geological Survey has routinely analyzed the -250 mesh ("G" fraction) and -10 mesh ("T" fraction) in addition to the non-magnetic heavy mineral concentrate ("H" fraction). Published drill datasheets contain gold values for the three fractions determined by INAA with a 20 ppb detection limit. "G" and "T" fraction samples were reanalyzed by Fire Assay-Direct Coupled Plasma (FA-DCP). Although a 1.0 ppb detection limit can be achieved by this method using a 20 g sample, the smaller sized samples available for reanalysis resulted in higher detection limits for most samples, particularly the "G" series.

The results of the FA-DCP gold analysis of the "G" and "T" fractions (and INAA analysis of the H fraction) for Holes 84-24 and 28 are presented in Figure 080.2. Also listed are the number of gold grains recovered during sample processing.

What is clearly evident is the relationship between the number of gold grains and the heavy mineral geochemistry. Variation in the geochemical values for samples containing the same or similar numbers of gold grains is largely due to differences in the size of the gold grains between samples. For example, samples 24-03 and 24-04 each contain 20 gold grains, however, 24-03 has a geochemical value of 16 000 ppb compared to 3300 ppb for 24-04. The difference is explained by the presence in 24-03 of a gold grain measuring 1250 by 600 microns, several times larger than any grain found in 24-04. The fact that size of the gold grain(s) affects the geochemical response to a greater degree than number of grains is further evidenced by sample 24-05. While this sample contains 27 gold grains it produced a geochemical value in the "H" fraction of just 1700 ppb. The bulk of the gold grains in this sample are small, with 15 grains having dimensions of 100 by 100 microns or less and the largest grain measuring 250 by 200 microns.

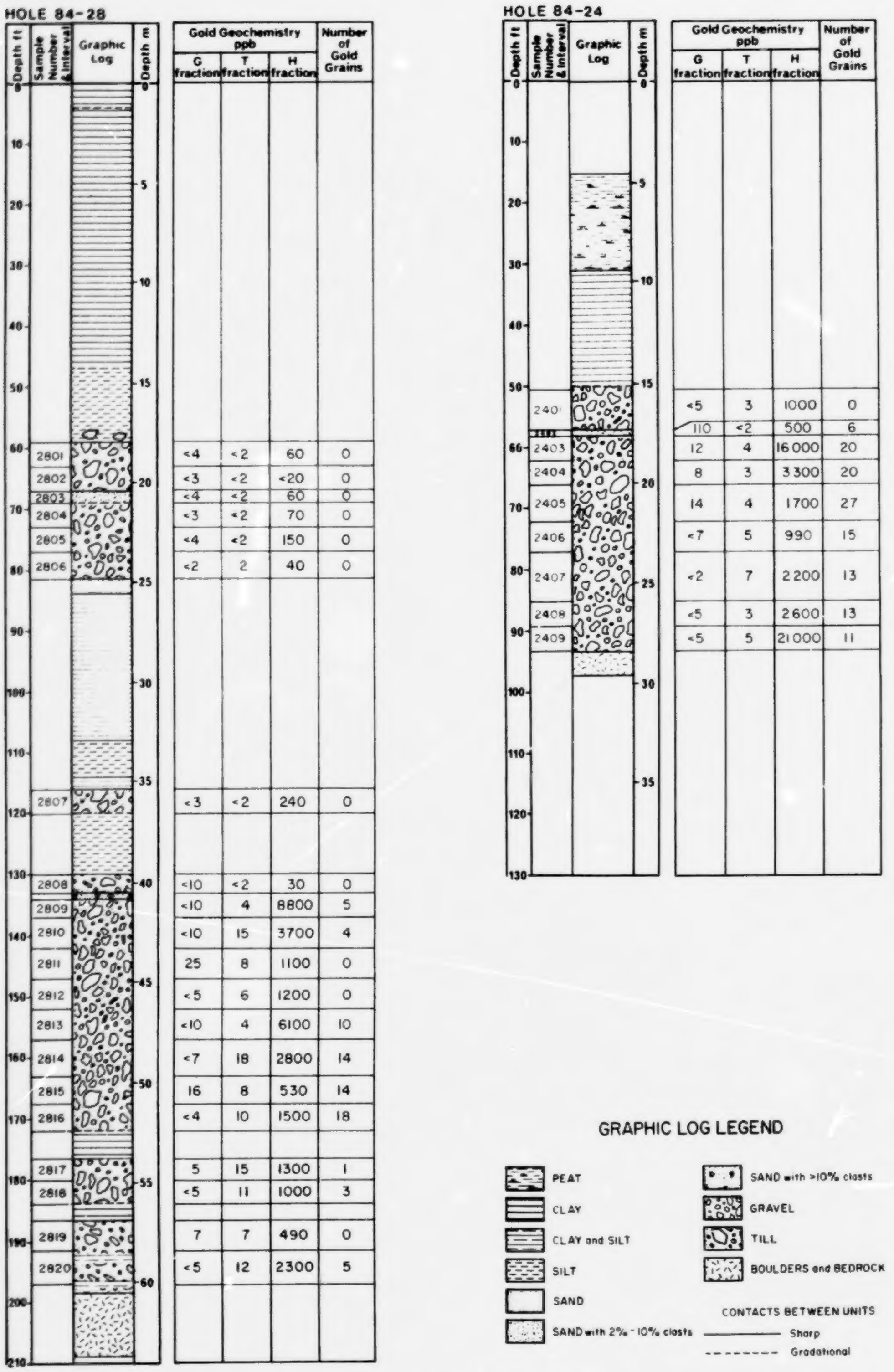
A review of the "T" fraction gold values indicates the -10 mesh material has a gold background value of <2 ppb as shown by the upper, non-anomalous section of hole 84-28. The lower, anomalous portion of the hole, samples 09 to 20, has "T" fraction values ranging from 4 to 18 ppb. The anomalous section of hole 84-24, samples 03 to 09, has "T" fraction values ranging from 4 to 7 ppb.

It appears that the -10 mesh fraction of till samples weakly reflects gold mineralization. It is doubtful whether the values are sufficiently elevated above background that they would warrant the routine use of this fraction in exploration.

The interpretation of "G" fraction data is complicated due to the irregular detection level resulting from the varying small sample size. The absolute values that were obtained for the anomalous sections of holes 84-24 and 28 indicate that the "G" fraction does produce an elevated geochemical response. As in the case of the "T" fraction, the degree by which the values exceed background is slight, making the use of the -250 mesh material difficult.

ACKNOWLEDGMENTS

Work described herein was completed by the authors with the competent assistance of J.T. Aultman and W.G. Powell. The Ontario Geological Survey wishes to thank individuals and companies who were party to discussions, and who allowed sampling on their properties.


HOLE 84-28
Depth ft
Sample Number & Interval
Graphic Log
Depth m
HOLE 84-24
GRAPHIC LOG LEGEND
PEAT
CLAY
CLAY and SILT
SILT
SAND
SAND with 2% - 10% clasts
SAND with >10% clasts
GRAVEL
TILL
BOULDERS and BEDROCK
CONTACTS BETWEEN UNITS
Sharp
Gradational

HOLE 84-28

Sample Number & Interval	Gold Geochemistry ppb			Number of Gold Grains
	G fraction	T fraction	H fraction	
2801	<4	<2	60	0
2802	<3	<2	<20	0
2803	<4	<2	60	0
2804	<3	<2	70	0
2805	<4	<2	150	0
2806	<2	2	40	0
2807	<3	<2	240	0
2808	<10	<2	30	0
2809	<10	4	8800	5
2810	<10	15	3700	4
2811	25	8	1100	0
2812	<5	6	1200	0
2813	<10	4	6100	10
2814	<7	18	2800	14
2815	16	8	530	14
2816	<4	10	1500	18
2817	5	15	1300	1
2818	<5	11	1000	3
2819	7	7	490	0
2820	<5	12	2300	5

HOLE 84-24

Sample Number & Interval	Gold Geochemistry ppb			Number of Gold Grains
	G fraction	T fraction	H fraction	
2401	<5	3	1000	0
	110	<2	500	6
2403	12	4	16000	20
2404	8	3	3300	20
2405	14	4	1700	27
2406	<7	5	990	15
2407	<2	7	2200	13
2408	<5	3	2600	13
2409	<5	5	21000	11

Figure 080.2. *Graphic logs and comparison of gold geochemistry from three till fractions.*

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081. Gold Metallogenesis Along the Pipestone and Destor-Porcupine Deformation Zones and Associated Structures

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This project is part of Operation Black River-Matheson (BRIM) and was funded equally by the Ontario Ministry of Northern Development and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

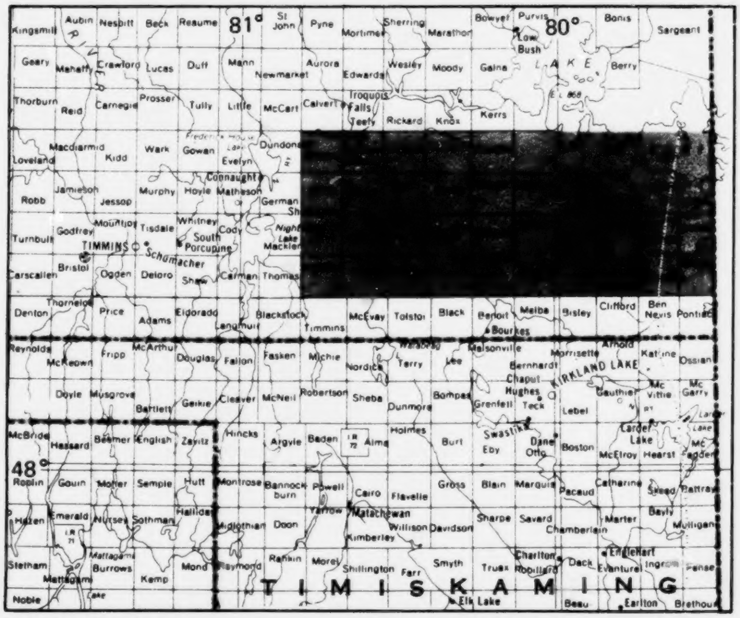
This study involves gold deposits along the Pipestone and Destor-Porcupine Fault Zones and related structures, between Nighthawk Lake and the Quebec border (Whittaker and Malczak 1984; Whittaker 1985). In addition, gold deposits along later structures that crosscut the Destor-Porcupine Fault Zone (DPFZ) were also examined. This work has been done by the Mineral Deposits Section of the Ontario Geological Survey, beginning in 1983, as a contribution to the Black River Matheson (BRIM) program.

REGIONAL GEOLOGY

The study area is part of the southwestern Abitibi Greenstone Belt (Figure 081.1; MERQ-OGS 1983) which consists of regionally deformed and metamorphosed mafic to felsic metavolcanics and metasediments. The lower parts of the supracrustal succession are characterized by komatiitic flows and hypabyssal ultramafic intrusions (e.g. Stoughton-Roquemaure Group flows in Munro Township, Pyke *et al.* 1973; Jensen and Langford 1983, 1985; Dundonald Sill, Tisdale Group in Dundonald and Clergue Townships, Naldrett and Mason 1968). The middle volcanic rocks are represented by tholeiitic iron and magnesium basalt-andesites of the Kinojevis Group (Jensen and Langford 1983, 1985) and the upper parts become steadily more felsic with dacitic to rhyolitic flows and pyroclastic rocks of the Blake River Group (Jensen and Langford 1983, 1985).

The predominantly mafic volcanic succession has been regionally deformed into an east-plunging synclinorium with the nose of the structure located at Timmins. The southern limb trends through the Kirkland Lake area and the northern limb strikes easterly through the Matheson area, south of Lake Abitibi and eastwards to the Quebec border, Noranda, and Destor. Trondhjemitic to syenitic stocks intrude and locally metamorphose regional greenschist facies (Cherry 1983) volcanic rocks to contact aureoles at almandine amphibolite facies (e.g. Murphy-Garrison open pit, west-central Garrison Township). Regional scale intrusions are emplaced into the metavolcanic succession with the Abitibi Batholith in the northeastern corner of the study area and the Watabeag Batholith in the southwestern part.

A series of ductile to brittle deformation zones transgress the volcanic and volcanogenic metasediments of the study area with an approximately easterly strike. A later generation of deformation zones, with northeast to northwest trends, crosscuts these east-striking zones. All generations of deformation zones have related gold deposits and occurrences (Figure 081.1, Table 081.1). These deformation zones



LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

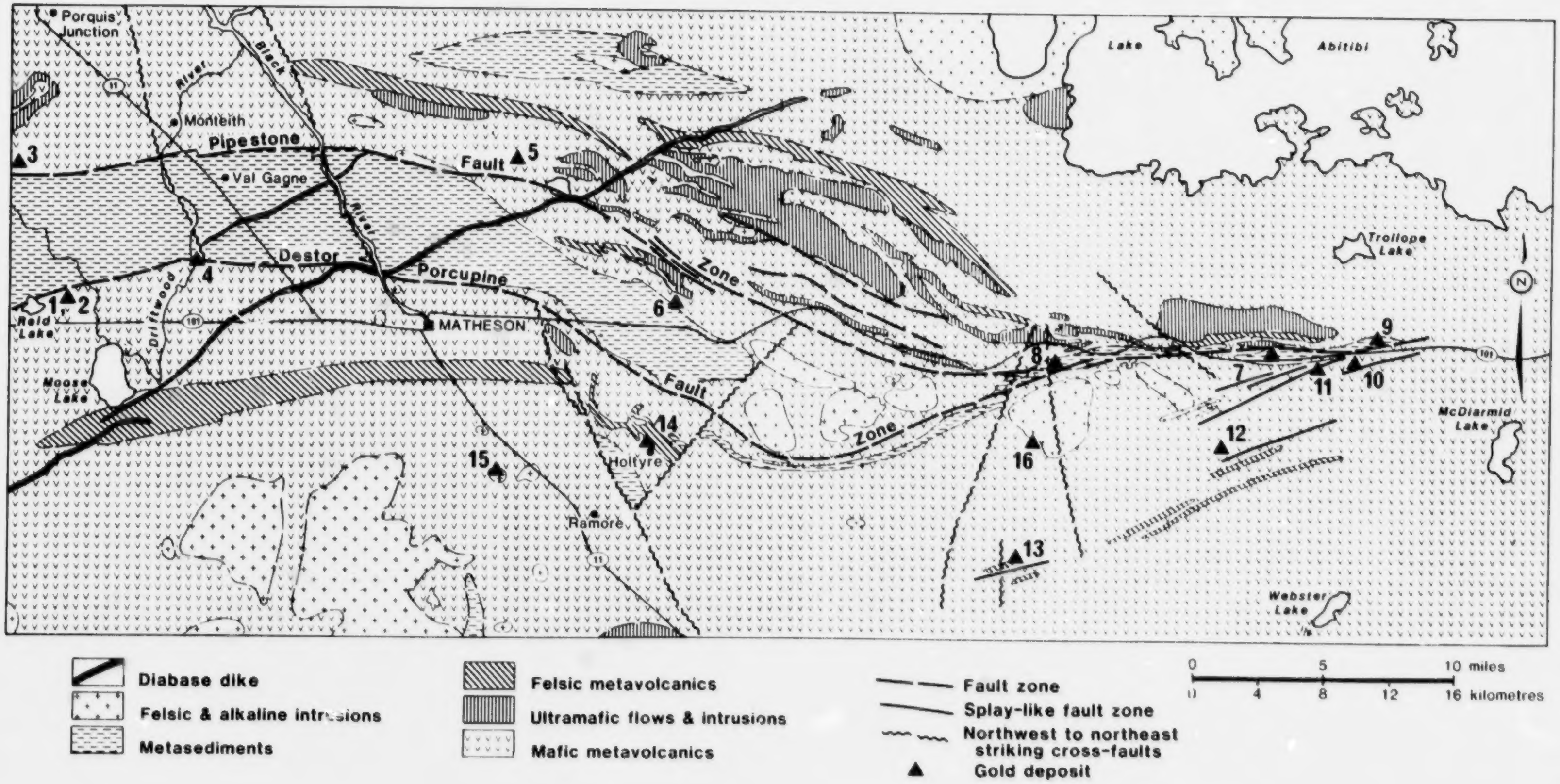

Porquis Junction
Monteith
Val Gagne
Black River
Driftwood
Reid Lake
Moose Lake
MATHESON
Holtyre
Ramore
Lake Abitibi
Trollope Lake
McDiarmid Lake
Webster Lake
Pipestone Fault
Destor
Porcupine
Zone
Fault
Zone
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
11
101
N
Diabase dike
Felsic & alkaline intrusions
Metasediments
Felsic metavolcanics
Ultramafic flows & intrusions
Mafic metavolcanics
Fault zone
Splay-like fault zone
Northwest to northeast striking cross-faults
Gold deposit
0
5
10 miles
0
4
8
12
16 kilometres

Figure 081.1. *Gold deposits and three deformation zones in rocks of the southwestern Abitibi Greenstone Belt. The numbers on the map refer to the mines or deposits listed in Table 081.1.*

DEFORMATION ZONE	MINE / DEPOSIT Production status present ● past ⊙	GOLD-TEXTURE Free	inclusion and/or rim py.	aspy.	cpy.	HOST ROCK ALTERATION carb.	sil.	ser.	K	anh.	oxi. (hem.)	VEIN GOLD qtz. vein	carb. vein	ASSOCIATED ASSEMBLAGE py.	aspy.	cpy.	gal.	sph.	tet.	spec.
FZ Destor-Porcupine & Pipestone Faults (E-striking)	1. St. Andrew Goldfields Mine (under development)	×	×		×	×	×	×				×		×	×	×				
	2. St. Andrew Goldfields-N2 zone	×	×		×	×								×		×				
	3. Clavos deposit	×	×	×		×	×	×				×	×	×	×					
	4. Consolidated Montclerg deposit	×	×		×	×	×	×				×	×	×	×	×				
	5. Maude Lake deposit	×	×				×					×		×	×					
	6. Croesus Mine ⊙	×		×		×		×				×		×	×	×		×		
	7. Teddy Bear Valley Mine ⊙	×				×						×		×	(+ tourmaline)					
	8. Garrcon deposit	×	×			×		×				×		×	×	×				
	9. East Zone deposit	×				×		×				×		×	×	×	×	×	×	×
SF Splay-like Faults (ENE-striking)	10. Mattawasaga Zone deposit	×	×			×	×	×			×			×		×				×
	11. McDermott Zone deposit	×	×			×	×	×			×			×		×				×
	12. Golden Harker Mine ⊙	×	×			×	×					×		×		×				×
	13. Thackeray Township occurrence	×	×			×	×	×			×			×		×				
CF Cross-faults (NW to NE-striking)	14. Ross Mine ●	×	×			×	×	×	×	×	×	×	×	×		×	×	×	×	×
	15. Canadian Arrow Mine ⊙		×						×		×	×		×		×				
	16. Murphy-Garrison Mine ⊙		×			×						×		×		×				

Table 081.1. *Structural, textural, and alteration characteristics and associated mineralogy of gold mines and deposits in the vicinity of three deformation zones, southwestern Abitibi Greenstone Belt.*

have been grouped into three categories: the major eaststriking zones (e.g. the DPFZ and the Pipestone Fault Zone), splay-deformation zones striking east-northeast, and northwest to northeasterly striking cross-faults which offset the DPFZ in places. This three-fold deformation system crosscuts a variety of volcanic, sedimentary, and intrusive lithologies. Gold deposits and occurrences are related to these structures and are independent of host lithology (Figure 081.1, Table 081.1).

GOLD DEPOSITS AND OCCURRENCES

Significant gold deposits along main east-striking structures include the St. Andrew Goldfields Mine (Malczak 1985, this volume) adjacent to the DPFZ, the Clavos Property (Canamax Resources Incorporated) being explored at the Pipestone Fault Zone, and the East Zone (American Barrick Resources Corporation) in the DPFZ near the Quebec border. Gold deposits within the main deformation zones are characterized by their association with hosting quartz and quartz-carbonate veins. Gold is found free and as inclusions and discontinuous rims on pyrite. Gold is less commonly found with other sulphides which include chalcopyrite, galena, sphalerite, and tetrahedrite, an assemblage found in quartz veining at the East Zone, Holloway Township.

Splay-like structures are also the loci of several gold occurrences, which decrease in volume and continuity away from their junction with the DPFZ. The McDermott and Mattawasaga Deposits (American Barrick Resources Corporation and Canamax Resources Incorporated, respectively) are examples of these. They occur in silicified and oxidized mafic rocks where hematite has imparted a purple hue to silicified auriferous host rocks. Alteration is most intense, and gold values highest, in brecciated zones within the splay-like deformation zone. Gold mineralization is typically associated with disseminated secondary pyrite anhedra. Alteration is pervasive in and around breccia zones and weakens outwards with corresponding decreases in gold tenor. A gold halo is superimposed on altered rocks of the deformation zone with higher values at brecciated centres where silicification, oxidation to hematite, and carbonatization are most complete.

Northeast- and particularly northwest-striking deformation zones, which may reflect the Montreal River Lineament passing through the Timmins-Porcupine gold camp, have gold and silver deposits associated with them. The Ross Mine (Troop 1985 , this volume), an example of this association, is bounded by deformation zones with northeasterly and northwesterly trends. The Thackeray Township Occurrence also exhibits structural control over the location of alteration and gold mineralization where a north-striking deformation zone (mylonitic), approximately 3 m wide, intersects an east-striking splay-like structure.

Alteration is variable in degree and type between classes of structure and along similar structures. Along the east-striking main deformation zones, carbonatization and sericitization are most commonly associated with auriferous quartz and quartz carbonate veining. Along the east-northeast-striking McDermott splay, silicification and oxidation are important associates of gold, along with variable amounts of carbonate. Along northerly striking cross structures, carbonatization is predominant, as at the Thackeray Township Occurrence. At the Ross Mine, however, alteration is pervasive, complex, and involves types encountered at most other gold camps. This intricate style of alteration may reflect the depth and complexity of the deformation zones and the variety of fluid compositions that percolated along them.

CONCLUSIONS

Gold deposits within the southwestern Abitibi Greenstone Belt bounded by the study area can be related to three classes of deformation zones. Deposits are associated with:

1. main east-striking zones, such as the DPFZ and the Pipestone Fault Zone (e.g. St. Andrew Goldfields, Clavos, East Zone)
2. east-northeast-striking splay zones rooted in the DPFZ (e.g. McDermott Zone, Mattawasaga Zone)
3. northeasterly to northwesterly striking cross faults (e.g. Ross Mine)

Exploration for gold within the BRIM area is hampered by extensive lacustrine clay cover and multiple glacial packages (Baker *et al.* 1985). Despite this, significant gold deposits may occur along the wider and more continuously developed east-striking deformation zones, along east-northeast-striking splay-like structures where rooted in the DPFZ, or along major northerly striking deformation zones. Interruptions in deformation zone continuity, such as where intersected by crosscutting faults or mylonite zones, are areas that would also be of interest for potential pipe-like auriferous alteration zones. Recognition of breccias, alteration types, and their intensity is similarly of importance for gold potential. It should be emphasized that disseminated gold in altered host rocks, as at the McDermott Deposit, occurs in the absence of significant quartz veining and represents a new mode of occurrence for a gold deposit within the study area.

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082. Report on the St. Andrew Goldfields Deposit, the Clavos Gold Deposit, and the Montclerg Gold Prospect, District of Cochrane

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INTRODUCTION

Investigations of gold mineralization in the Black River-Matheson (BRIM) area, initiated in 1984 (Whittaker and Malczak 1984; Malczak 1985; Whittaker 1985), continued in 1986 with further studies of the St. Andrew Goldfields Deposit on the Destor-Porcupine Fault Zone (DPFZ) and initial investigations of the Clavos Deposit and the Montclerg Prospect on the Pipestone Fault Zone (PFZ).

Work at the St. Andrew Goldfields Deposit comprised examination and sampling of new underground development and sampling of drill core from other previously known and newly discovered mineralized zones. The Clavos Deposit was visited and core samples from representative drillholes were collected. At the Montclerg Prospect, outcrop and drill core were examined and sampled. Information acquired from these deposits will complement other studies to develop a metallogenic model of gold mineralization in the BRIM area (Whittaker and Malczak 1984). Figure 082.1 shows the locations of the St. Andrew Goldfields and Clavos Deposits and the Montclerg Prospect.

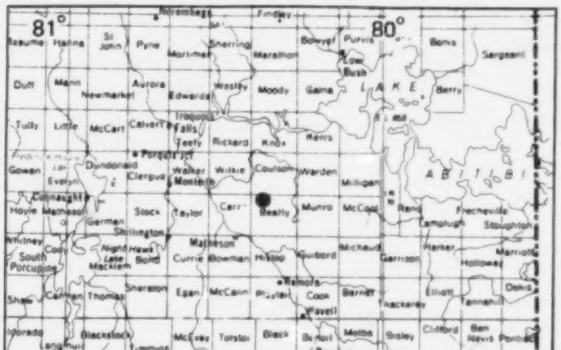
ST. ANDREW GOLDFIELDS DEPOSIT

The St. Andrew Goldfields Deposit is located in southcentral Stock Township, 50 km east of Timmins. It is situated within the Stoughton-Roquemaure Group of mafic and ultramafic rocks along the Destor-Porcupine Fault Zone (DPFZ). A description of the deposit is given by Malczak (1985).

A new drift section on the third level and a new sublevel between the third and fourth levels were opened in the main mineralized zones west of the shaft during the Fall and Winter of 1985/86. All development was restricted to highly altered sections of a succession of mafic flows. Gold mineralization in these areas is identical to that described in the previous report.

Until recently, underground exploration had only defined gold mineralization in zones within a vertical, east-northeast-trending wedge of massive and pillowed mafic flows. These zones subcrop west of the shaft and form a series of irregular pods which plunge about 240°/60°. In 1986, a new mineralized zone (N2) was discovered north of the shaft within a relatively undeformed block of material bounded to the north and south by splays of the DPFZ. It appears to be subparallel to the discovery zone and plunges about 50° west.

The host unit to this newly discovered mineralized zone is a grey, medium-grained, moderately foliated, altered and veined mafic or ultramafic rock. Green, fuchsite-bearing varieties of this rock type are interlayered with the host and together they form part of an extensive assemblage which surrounds the mafic volcanic wedge hosting the original mineral-


81°
80°
48°
Hanna
St John
Pyne
Mortimer
Sherring
Marathon
Purvis
Bonis
Sargeant
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Gaina
LAKE
Low Bush
Berry
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Richard
Knox
Kerrs
Gowan
Evelyn
Dundonald
Clergue
Porquis Jct
Walker
Wilkie
Monteith
Coulson
Warden
Milligan
ABITIBI
Connaught
Hoyle
Matheson
German
Stock
Taylor
Carr
Beatty
Munro
McCool
Rand
Lamplugh
Frecheville
Stoughton
Whitney
Cody
South Porcupine
Shillington
Night Hawk Lake
Bond
Mackiem
Matheson
Currie
Bowman
Hislop
Guibord
Michaud
Garrison
Harker
Marriott
Holloway
Shaw
Carman
Thomas
Sheraton
Egan
McCann
Playfair
Ramore
Cook
Bisley
Barnett
Thackeray
Elliott
Tannahill
Dokis
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Bourkes
Melba
Sisley
Clifford
Ben Nevis
Pontiac
Dupley
Fallon
Fesken
Michie
Nordica
Terry
Lee
Maisonville
Morrisette
Arnold
Katrine
Dewan
Bernhardt
Chaput Hughes
KIRKLAND LAKE
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Grenfell
Teck
Lebel
Gauthier
Mc Vittie
Mc Garry
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Otto
Boston
Larder Lake
McElroy
Hearst
Larder
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Skead
Rattray

LOCATION MAP

Scale : 1:1 584 000 or
1 inch to 25 miles

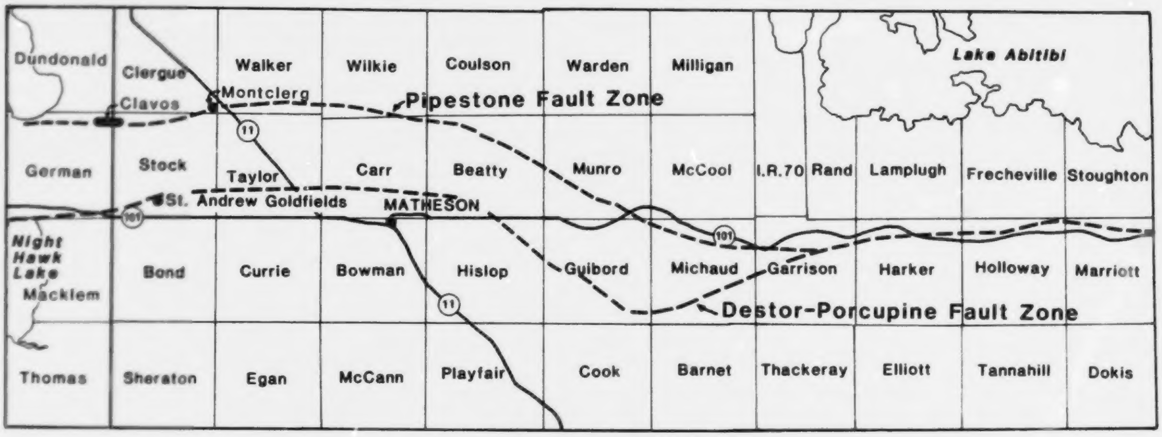

Dundonald
Clergue
Clavos
Walker
Montclerg
Wilkie
Coulson
Warden
Milligan
Lake Abitibi
Pipestone Fault Zone
11
German
Stock
Taylor
Carr
Beatty
Munro
McCool
I.R.70
Rand
Lamplugh
Frecheville
Stoughton
St. Andrew Goldfields
MATHESON
101
Night Hawk Lake
Macklem
Bond
Currie
Bowman
Hislop
Guibord
Michaud
Garrison
Harker
Holloway
Marriott
Destor-Porcupine Fault Zone
Thomas
Sheraton
Egan
McCann
Playfair
Cook
Barnet
Thackeray
Elliott
Tannahill
Dokis

Figure 082.1. *Location map of the St. Andrew Goldfields and Clavos Deposits and the Montclerg Prospect.*

ized zone. Chlorite and iron carbonate are the major constituents of the host with up to 15 percent disseminated, euhedral pyrite (3 mm in diameter) throughout the mineralized zone. Little veining is evident within mineralized sections of drill core from the N2 zone. In polished thin section, gold occurs as very fine, irregular grains, usually with chalcopyrite, within pyrite grains, and along grain boundaries and microfractures in pyrite.

Drill results indicate undiluted reserves of about 365 700 tons at 0.281 ounce gold per ton in the N2 zone (The Northern Miner, June 09, 1986, p.3). Reported grades of the original zone are 735 625 tons at 0.135 ounce gold per ton or 525 626 tons at 0.168 ounce gold per ton (The Northern Miner, July 18, 1985, p.3).

CLAVOS DEPOSIT

The Clavos Deposit, the focus of a 2/3:1/3 joint venture between Canamax Resources Incorporated and Bruneau Mining Company Limited, is located on the PFZ about 8.5 km northwest of the St. Andrew Goldfields Deposit. The fault occurs at the contact between the Stoughton-Roquemaure Group to the north and the Porcupine Group sedimentary rocks to the south.

Results of drill programs to date indicate three mineralized zones along a 1.5 km segment of the fault (Figure 082.2). The generalized geological plan and cross section of the "Discovery Zone", shown in Figures 082.2 and 082.3, respectively, are reproduced from company maps (B.J. McKay, Project Geologist, Canamax Resources Incorporated, personal communication, 1986). The stratigraphic succession strikes east-west and dips steeply south. It is relatively consistent along strike and is offset locally by late stage north-south cross faults.

The footwall rocks are ultramafic rocks of the Stoughton-Roquemaure Group, largely composed of dark green, medium-grained, talc-bearing serpentinized peridotite and/or komatiitic flows. Well-developed spinifex textures occur locally. A well-developed fault plane occurs at the southern edge of the serpentinites. The fault is marked by gouge over widths of up to 4 m. Ultramafics on either side of the fault are brecciated over a total width of up to 30 m.

Gold mineralization is restricted to a succession of pseudo-fragmental units enclosing an irregular, subparallel system of altered felsic dikes. This succession, in the "Discovery Zone", ranges in width from 15 to 45 m. Units of both serpentinite and metasediments are intercalated with the pseudo-fragmental units.

The pseudo-fragmental units are strongly foliated and appear to be composed of buff brown and light grey, fine-grained, flattened angular fragments within a chlorite-rich matrix. Core samples resemble flattened lapilli or sedimentary clasts. Fragments are generally less than 2 to 3 cm long and 0.5 cm wide. Thin section examination shows the fragments to be aggregates of fine-grained carbonate and few fine, irregular quartz and feldspar grains with a smaller percentage of chlorite and minor sericite. The matrix consists of chlorite with minor sericite. Chlorite imparts a strong foliation throughout the rock, both in the fragments and matrix.

A system of strongly altered felsic dikes within the pseudo-fragmental zone hosts most of the gold mineralization. The dike system appears to be boudinaged or splayed with widths ranging from less than 1 to 18.5 m. In some localities, two or more distinct dikes may parallel one another. The dikes are generally light grey, fine grained, massive, and highly siliceous with minor carbonate veining. No relict textures are preserved. Quartz vein networks form along the margins of the dikes up to a few metres into the pseudo-fragmental units. The higher gold values were detected either within the dikes or at their margins. In sections where the dike complex is wide, two or more mineralized drill core segments can often be detected. Gold is closely associated with fine- to medium-grained (<5 mm), euhedral, acicular arsenopyrite grains which may form up to 10 percent of the mineralized zone. In addition, lesser pyrite and minor chalcopyrite are also present, usually as fine

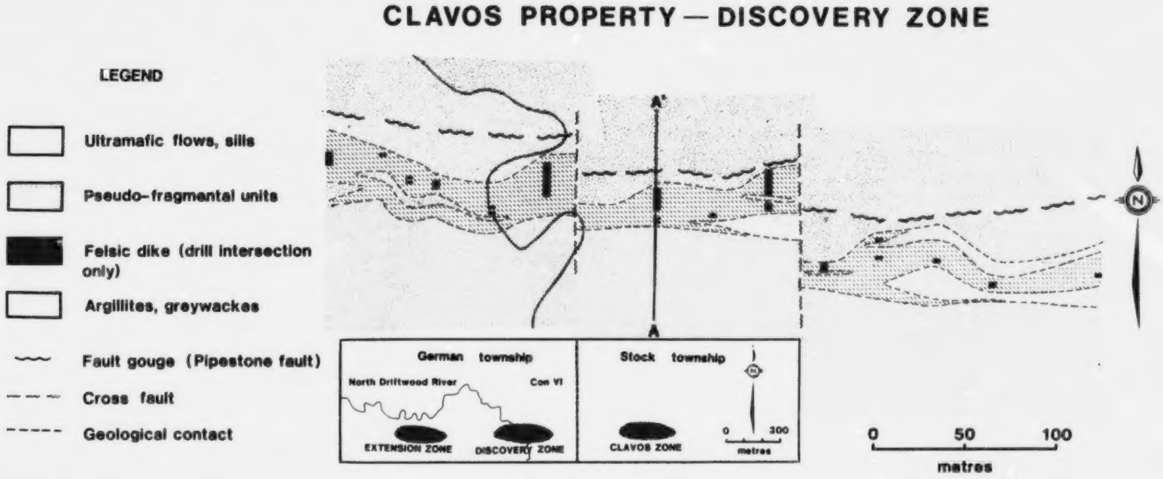


Figure 082.2. Subsurface geological plan of the Clavos Deposit constructed from drill logs. Reproduced from company maps by B.J. McKay, Canamax Resources Incorporated.

disseminated grains. Free gold occurs in quartz veins within the mineralized zone. Core intersections of the felsic dike from drill holes "e", "f" and "a" (Figure 082.3) assayed 3.01 g/t gold over 6.0 m, 5.58 g/t gold over 26.7 m and 3.70 g/t over 2.0 m, respectively. Assays of the northern and southern margins of the dike from holes "d" and "a" are: 5.67 g/t over 2.4 m, 1.80 g/t over 6.0 m, 3.45 g/t over 2.0 m, and 3.87 g/t over 1.5 m, respectively (B.J. McKay, Project Geologist, Canamax Resources Incorporated, personal communication, 1986).

Argillites and wackes of the Porcupine Group form the southern boundary of the pseudo-fragmental zone. Although the argillites and pseudo-fragmental units are interlayered with one another in the contact zone, the boundary was set at the location of the last major argillite unit. This also marks the general location of a narrow silicified zone within the pseudo-fragmental unit which is also mineralized. Graphite, and occasionally arsenopyrite, are present in this zone. Samples from drill holes "d" and "a" assayed 4.1 g/t gold over 1.8 m and 3.99 g/t over 1.1 m respectively (B.J. McKay, Project Geologist, Canamax Resources Incorporated, personal communication, 1986). The argillites south of this zone are dark grey, very fine grained, strongly foliated, and laminated and locally isoclinally folded. Coarse, euhedral pyrite is disseminated in places.

Drill results from the Discovery Zone indicate about 470 000 tons grading 0.212 ounce gold per ton (The Northern Miner, June 16, 1986, p.325).

MONTCLERG PROSPECT

Additional information on the nature of mineralization along the PFZ was obtained from an examination of drill core and limited outcrop at the Montclerg Prospect. The prospect is located in the southeastern corner of Clergue Township about 10 km east of the Discovery Zone on the Clavos Deposit (Figure 082.1). Consolidated Montclerg Mines Limited is currently carrying out the exploration program.

Outcrop on the eastern side of the Driftwood River exposes a 30 m wide succession dominated by felsic fragmental rocks. The southern part is composed of a fine-grained weakly foliated quartz-feldspar porphyry or intermediate porphyritic flow. The rock contains about 15 to 20 percent phenocrysts which are predominantly altered, subhedral feldspar with minor quartz. Grains are usually <2 mm in length. The matrix is composed mostly of carbonate and chlorite. In localities, narrow "variolitic"-like zones extend for >2 m across the outcrop. These zones are distinguished by a concentration of fine, rounded buff-coloured spots within a darker grey matrix. Further north this rock also contains a few subrounded medium-grained quartz diorite and fine-grained massive mafic or intermediate fragments up to 30 cm in diameter. A narrow, weakly offset, chilled contact zone marks the boundary with another porphyritic unit. The fine-grained chill zone grades into a finely autobrecciated rock which then quickly grades into a fragmental rock with lapilli size fragments. Gold associated with disseminated arsenopyrite and pyrite was detected within a relatively narrow zone within the fragmental rocks at the northern end of the outcrop. The mineralized rock is strongly carbonatized and sericitized; however, quartz phenocrysts can still be identified. Two sets of barren quartz veins cut across the outcrop.

Gold mineralization was detected in two of three holes drilled immediately east of the outcrop area. The barren hole was drilled northward, intersecting a mafic fragmental unit, sericite-chlorite schist, and finally an extensive section of altered mafic pillowed flows. The holes drilled southward passed through a succession of felsic units into brecciated mafic volcanic rocks. Gold is associated with arsenopyrite-rich

DISCOVERY ZONE — CROSS SECTION

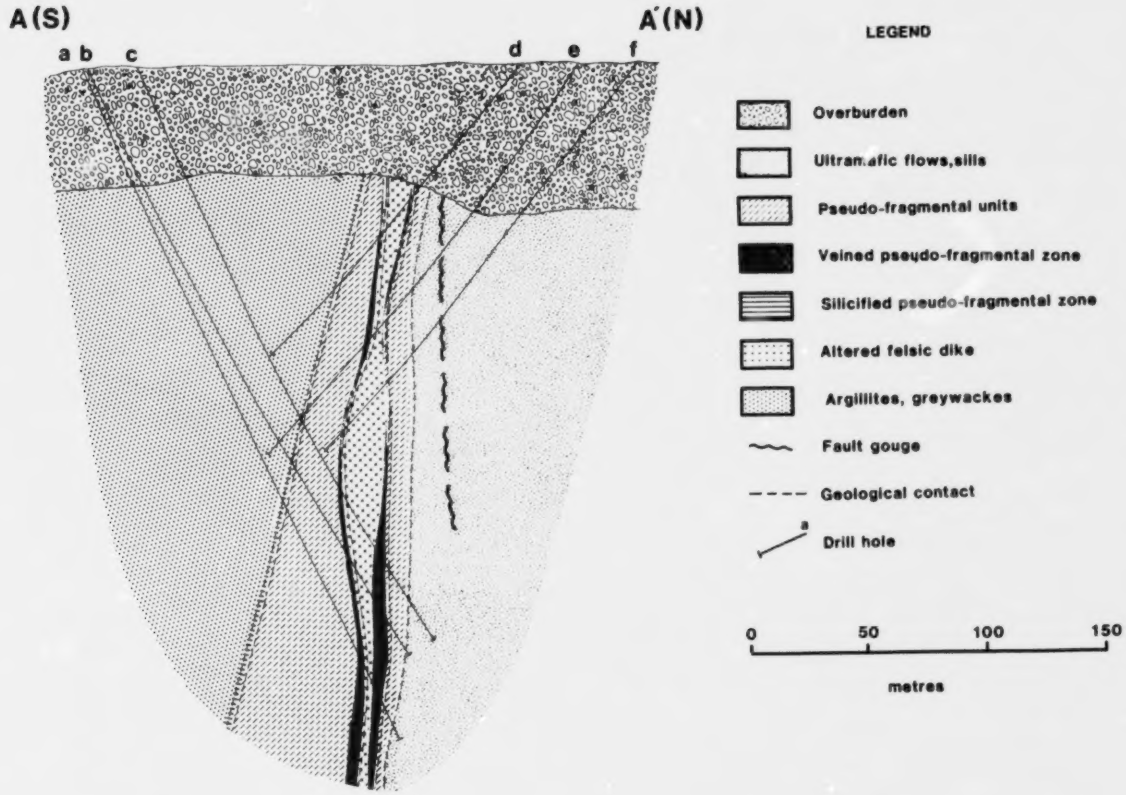

A(S)
A'(N)
a b c
d e f
LEGEND
Overburden
Ultramafic flows, sills
Pseudo-fragmental units
Veined pseudo-fragmental zone
Silicified pseudo-fragmental zone
Altered felsic dike
Argillites, greywackes
Fault gouge
Geological contact
Drill hole
a
0
50
100
150
metres

Figure 082.3. *Geological cross-section of the Discovery Zone, Clavos Deposit. Reproduced from company maps by B.J. McKay, Canamax Resources Incorporated.*

zones both within the felsic and mafic rock units. These zones appear to be more common near or at the contacts between distinct felsic units and between the felsic and mafic volcanic rocks. In one hole, two anomalous zones were detected in the felsic rocks and one within the mafic volcanic rocks. These zones assay 0.07 ounce gold per ton over 20 feet, 0.102 ounce gold per ton over 20.5 feet, and 0.104 ounce gold per ton over 17 feet (J. Mountjoy, Consulting Geologist for Consolidated Montclerg Mines Limited, written communication, 1986). Mineralized zones contain up to 10 percent disseminated euhedral acicular arsenopyrite, up to 3 mm in length, and minor euhedral pyritohedrons.

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083. Multiple Orebody Types and Vein Morphologies, Ross Mine, District of Cochrane

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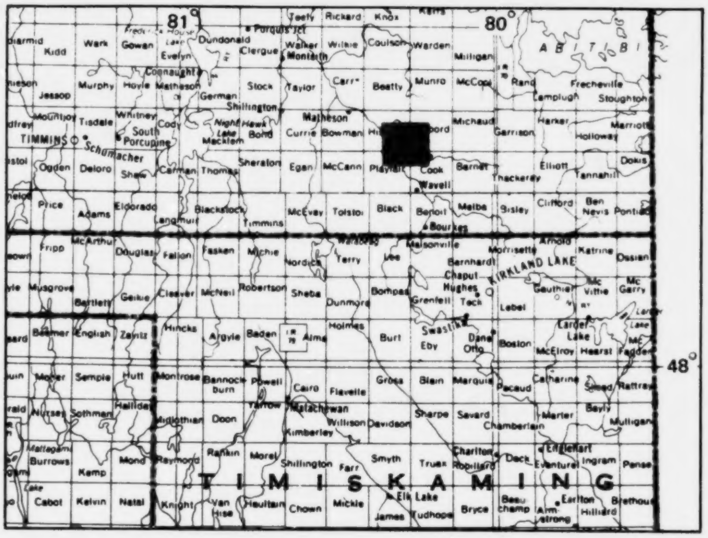
INTRODUCTION

During the 1985 field season, a preliminary appraisal of the geology of the Ross Au-Ag-(Cu) Mine and the surrounding area, was conducted in light of previous published work on the mine (Jones 1948; Akande 1982) and recent contributions to the understanding of the systematics and genesis of Archean lode gold deposits (Colvine *et al.* 1984). As a continuation in the study of ore geology and rock alteration at the Ross Mine, this report focuses on the detailed geology of several of the economically more important vein systems that comprise the mine environment. These have been studied from both surface and underground exposures. First, the geology and vein morphology of three distinct types of mineralization, as typified by various orebodies in the Ross Mine, are described. This is followed by a discussion of the possible spatial and temporal relationships between these ore types, and the potential for similarly mineralized systems of these types in the surrounding vicinity. The final component of this study (yet to be published) will document the mineralogical and chemical alteration of lithologies associated with the Ross orebodies within a paragenetic framework, and will assess the applicability of lithogeochemistry to gold mineralization of this type.

REGIONAL OVERVIEW

The Ross Mine, located in southeastern Hislop Township, is owned and operated by Pamour Mines Incorporated, controlled by Jimberlana Minerals Pty. of Australia, and has been in continuous operation since 1936. The mine will produce its one-millionth ounce of gold within the next year, while silver production currently stands at around 1.4 million ounces. A more detailed account of the mine and its operations is presented in Troop (1985). The position of vein lodes and single veins at the mine, with reference to several structural aspects of geology, and to the mine grid and main shaft, is shown on Figure 083.1.

Several problematic aspects of geology of the Hislop Township area pertain to the understanding of the Ross Mine. While a probable contact between older Stoughton-Roquemaure Group volcanic rocks and younger Kinojevis Group volcanic rocks transects the area near the mine, a distinct lack of surface exposure prohibits field confirmation of this contact. As an outgrowth of this problem, several scattered outcrops of supposed felsic rocks, extending through Bowman and Hislop Townships, were purported to be a continuous time horizon (Prest 1957; Leahy 1965), representing the uppermost cycle of volcanism in the Stoughton-Roquemaure Group. The Ross Mine area was included as part of this felsic package due to the presense of yellow-green, fragmental-looking, sericitic rocks, referred to as felsic fragmental and agglomerate in mine terminology (Jones 1948). However, the lithological character of these rocks is disputed by the author (Troop 1985) as more likely representing highly altered basaltic rocks (the mine sequence is dominated, in any case, by mafic volcanic flows and breccias). During the past field season, all previously mapped exposures of "felsic volcanics" were examined, and, with two exceptions, were found to be either a collection of highly strained


81°
80°
48°
ABITIBI
TIMISKAMING
TIMMINS
KIRKLAND LAKE
Kidd
Jessop
Murphy
Hoyle
Matheson
Tisdale
Whitney
Ogden
Deloro
Shaw
Carman
Thomas
Taylor
Mountjoy
Currie
Bowman
Hislop
Beatty
Munro
McCool
Michaud
Garrison
Guibord
McCann
Playfair
Cook
Barnet
Elliott
Tannahill
Black
Benoit
Melba
Sisley
Clifford
Ben Nevis
Teck
Lebel
Gauthier
Larder Lake
McVittie
McGarry
Boston
McElroy
Hearst
Catharine
Pacaud
Bayly
Marter
Chamberlain
Savard
Sharpe
Ingram
Evanturel
Dack
Robillard
Truax
Smyth
Farr
Elk Lake
James
Tudhope
Bryce
Beauchamp
Armstrong
Hilliard
Earlton
Brethour
Pense
Cabot
Kelvin
Natal
Knight
Van Hise
Chown
Mickle
Raymond
Rankin
Morel
Shillington
Kimberley
Willison
Davidson
Midlothian
Doon
Yarrow
Matachewan
Cairo
Flavelle
Gross
Blain
Marquis
Montrose
Bannockburn
Powell
Semple
Hutt
English
Zavitz
Argyle
Baden
Alma
Holmes
Burt
Eby
Otto
Gowan
Evelyn
Dundonald
Clergue
Walker
Wilkie
Coulson
Warden
Milligan
Rand
Frecheville
Stoughton
Lamplugh
Harker
Holloway
Marriott
Dokis
Thackeray
Wavell
Egan
Sheraton
Mackey
Bond
Night Hawk Lake
Cody
German
Shillington
Stock
Carr
Teefy
Rickard
Knox
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Bourkes
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Maisonville
Morrisette
Arnold
Katrine
Ossian
Bernhardt
Chaput-Hughes
Grenfell
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Beemer
Moher
Sothman
Halliday
Nursey
Burrows
Kemp
Mond
Cote
Mattagami
Swastika
Dane
Sweet
Rattray
Mulligan
Fadden

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

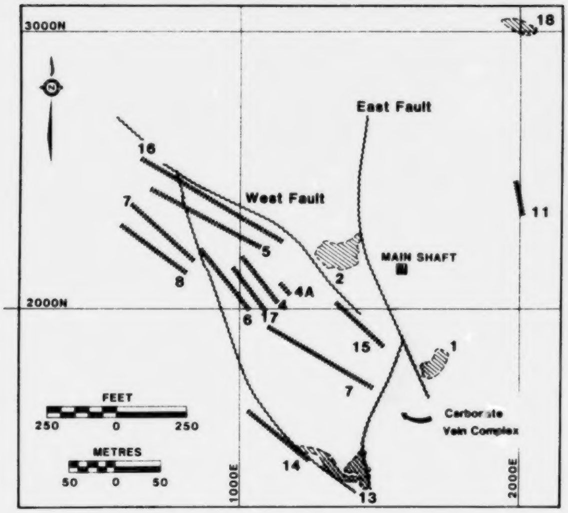


Figure 083.1. *Plan distribution of vein systems on the 450-foot level relative to some major structural features and the main Ross shaft. Heavy cross-ruled lines denote narrow single vein ores, while ruled areas show the position of vein lode ores.*

and sheared rock of indeterminate origin, or high level siliceous porphyritic intrusive rocks. The two exceptions occur:

1. along a central portion of the Pike River, where true massive felsic agglomerates are exposed in several steep rock faces; this observation has been interpreted similarly by R. Johnstone (Geologist, Ontario Geological Survey, personal communication, 1986)
2. in southern Bowman Township, where minor rhyolite, crosscut by porphyritic felsic dikes, is intercalated with basalts on the periphery of a gabbroic plug

While these exposures may well represent the uppermost limit of the Stoughton-Rcquemaure Group volcanic rocks, the Ross Mine stratigraphy is decidely not part of this package, on the basis of the observed exposures.

STRINGER ORES

The orebody geology and vein morphology of several pipe structures characterized by sheeted quartz veins and veinlets are described below. These are volumetrically the most significant ores in the Ross Mine.

THE 2 VEIN SYSTEM

The 2 Vein System is the most persistent and vertically extensive mineralized structure in the Ross Mine, extending from surface to the 3150-foot level, and open at depth. It is classified as a vertical pipe orebody characterized by blue-grey quartz 'A' stringers, as described in Troop (1985). The near-vertically plunging orebody bifurcates into two ore shoots around the 750-foot level, possibly as a result of some late fault offset (150 feet (46 m) horizontal separation between mineralized centres). From this level, the original 2 Vein portion continues to between the 900-foot and 1050-foot levels, while the 2B Vein portion, which plunges steeply to the west (78°/250°), continues to the deepest levels of the mine. Also of significance is the progressive change of orebody cross-section with depth, from roughly circular near surface, to elongate, trending northwesterly, with greater depth (*see* Figure 2 in Troop 1985). A very consistent gold grade of 0.14 ounce per ton has been recorded in this vein system throughout its production history. A sampling program for lithogeochemical purposes has been completed along the periphery of the 2 Vein System throughout the mine; geological mapping of sample sites has been augmented with detailed work on both the surface open pit and the 2850-foot level.

The Ross Mine Open Pit

The geology of the pit and ramp floor and walls (originally mapped at a scale of 1:240 or 1 inch to 20 feet) is presented in Figure 083.2. The 2 Vein System's surface orebody outline (stippled area) and the stope outline at the 150-foot level (dotted line) are shown in relation to the major lithological and structural features present.

The orebody is actually a lode composed of sheeted networks of blue-grey quartz stringers ('A') which dip from 75° to vertical, and trend generally in a northwesterly direction. Quartz stringers persist throughout the entire open pit area, but have a higher density within the area defined as ore (i.e. gold grade >0.10 ounce per ton). The stringers vary from less than 1 cm to up to 10 cm in width, and show some evidence of fracturing and stretching, and boudinage. Minute aggregates of pyrite, lesser chalcopyrite, and minor bornite, occur along the vein margins; microscopic free gold is associated with these sulphide minerals. The 'A' stringers are crosscut by a later barren set of white quartz veinlets which are generally from 0.5 to 1 cm in width and exhibit an *en echelon* sigmoidal form.

The principal host rock to mineralization in the pit area is a heavily carbonatized and sericitized unit which appears yellowish green to light apple green in fresh surfaces, but becomes increasingly yellowish brown with the degree of oxidation. This colour is a function of the iron content of the carbonate, which is probably a ferroan dolomite, and of the phengitic micas and inclusions of minute pods of fuchsite (mariposite) micas. The rock is moderately schistose, with the principal direction of cleavage parallel to 'A', stringer development dipping steeply to the northeast, and a weak passive crenulation of this cleavage directed at 105°. A mildly fragmental appearance has led previous workers (Jones 1948) to interpret this to be a felsic pyroclastic unit; however, the setting and mineralogical composition do not favour this interpretation. An alteration transition from the yellowish green unit to a dark green volcanic unit, can be observed at the crest of the west-central pit area. Heavy carbonatization persists in both units, but chlorite replaces phengite as the dominant phyllosilicate

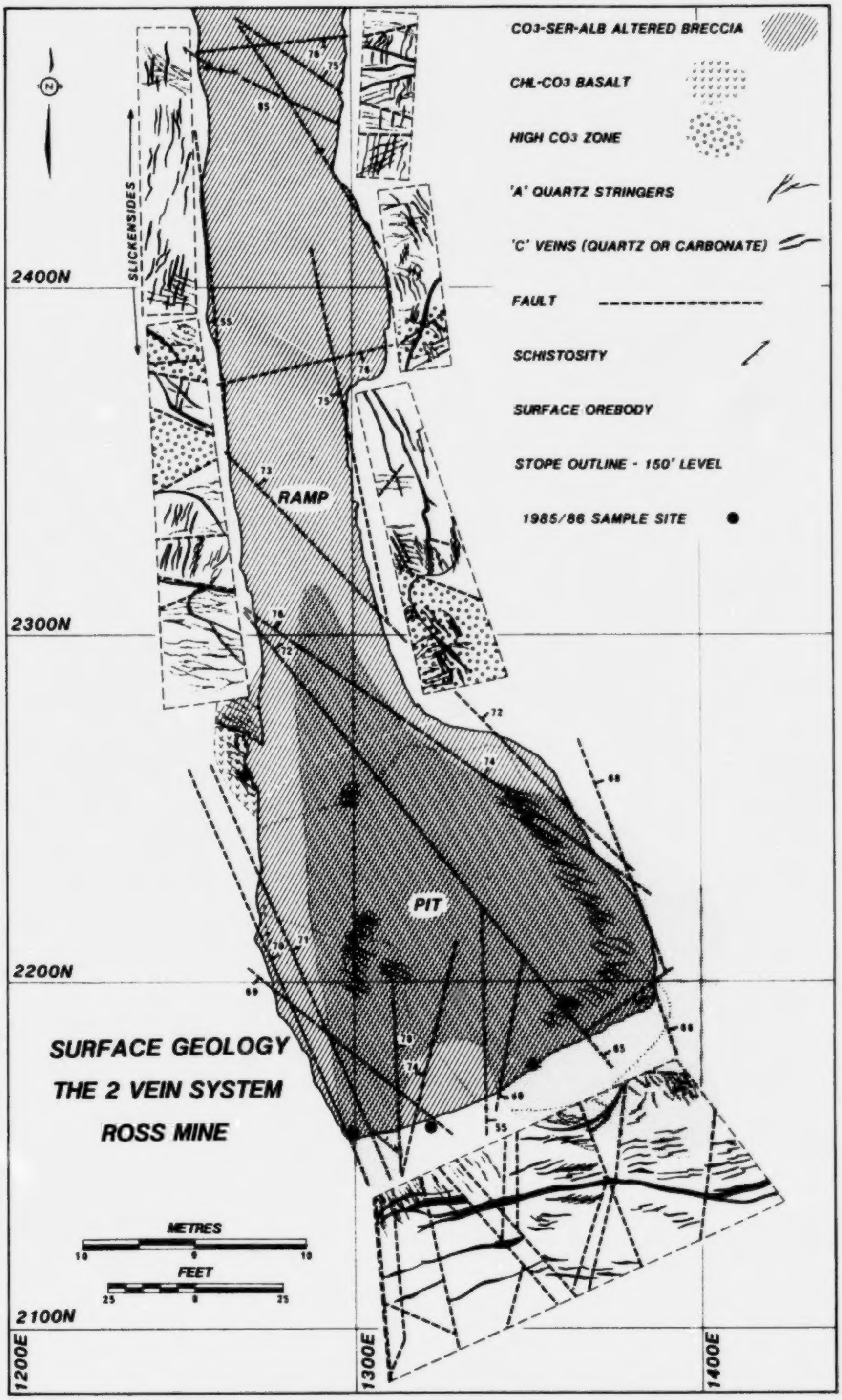

CO3-SER-ALB ALTERED BRECCIA
CHL-CO3 BASALT
HIGH CO3 ZONE
'A' QUARTZ STRINGERS
'C' VEINS (QUARTZ OR CARBONATE)
FAULT
SCHISTOSITY
SURFACE OREBODY
STOPE OUTLINE - 150' LEVEL
1985/86 SAMPLE SITE
N
SLICKENSIDES
RAMP
PIT
2400N
2300N
2200N
2100N
1200E
1300E
1400E
SURFACE GEOLOGY
THE 2 VEIN SYSTEM
ROSS MINE
METRES
10
0
10
FEET
25
0
25

Figure 083.2. *Detailed plan and section surface geology of the Ross Mine open pit floor, ramp and walls covering the uppermost extension of the 2 Vein system.*

in the dark green unit. An extensive network of 'A' stringers passes continuously from the sericite-carbonate to the chlorite-carbonate unit. Microscope examination of the chlorite-rich unit reveals basaltic flow textures, and is therefore proposed that the sericite-rich unit represents a highly altered equivalent of a basalt, and may also have suffered microbrecciation.

It is difficult to identify a consistent structural control on vein emplacement and mineralization in

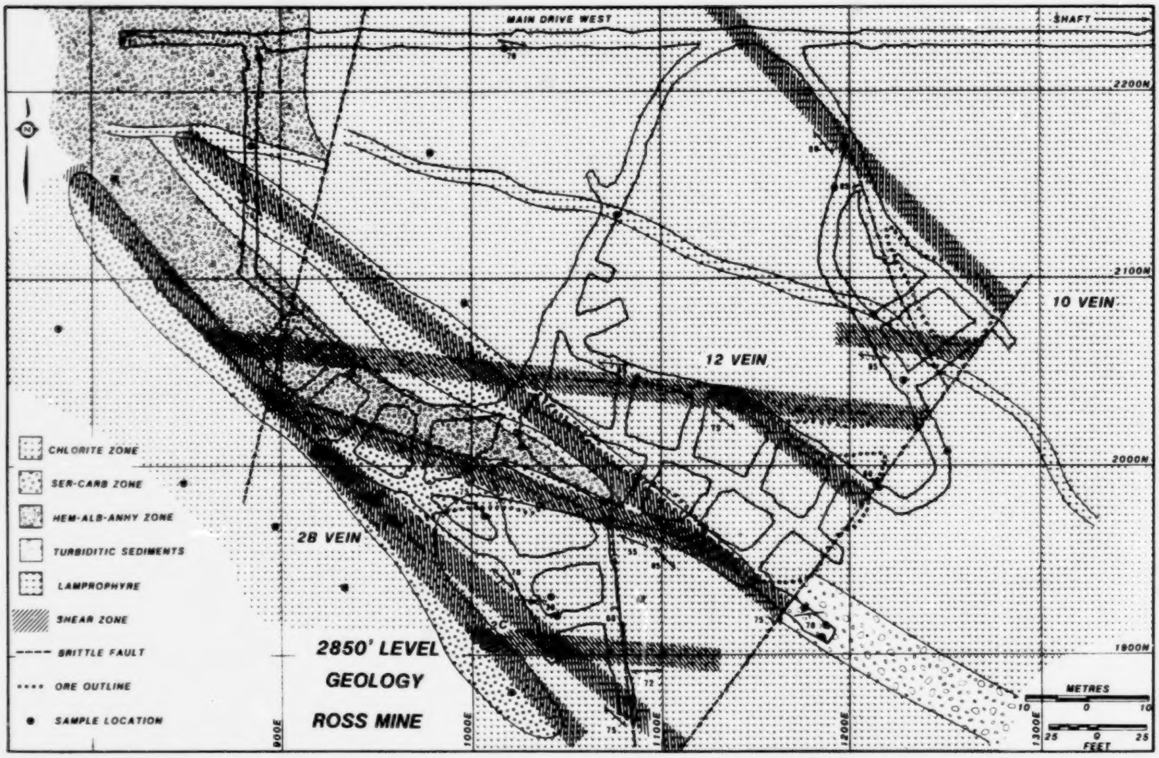


***Figure 083.3.** Detailed plan geology of the 2850-foot level including the 2B, 10 and 12 Vein Systems and vicinty. Geology from underground drift mapping and exploration diamond drill hole core logging. Major continuous zones of intense shearing are shown by the linear zones of ruled lines.*

the pit area. Numerous brittle faults, most of which trend northwesterly (Figure 083.2), have been mapped, and these generally do control the quartz stringer density and hence the absolute gold grade. Some of the north- to northeast-trending brittle faults have completely truncated the mineralization. 'A' stringers occur sub-parallel to the fault system that dips at 70° to the east and runs along the western side of the pit and are absent on the western side of the fault. A similar set of subparallel faults along the eastern limits of the pit is characterized by a very intense zone of carbonatization which appears to truncate mineralization to the north and east. Massive carbonate veins of variable width are found to occupy most fractures in the pit area, but are especially common in subhorizontal joints. These carbonate veins appear to have been a locus of continued strain, as a later still set of white quartz veins occurs as sigmoidally deformed tension gashes across the carbonate veins. Unmineralized quartz veins occupying subhorizontal joints are known as flat 'C' veins in mine terminology and are very common in the pit.

The strong northwest-trending cleavage persists throughout the pit area, and is parallel to mineralized quartz stringer emplacement. At the northern end of the pit, the weak crenulation of this cleavage observed in the ore zone becomes a much stronger schistosity, trending very nearly east-west and dipping vertically. In the deepest mine workings, a similar relationship between northwest-trending cleavage and west-trending schistosity has some bearing on ore localization.

The 2850-foot Level

The detailed geology of the area surrounding the 2B, 10, and 12 Vein Systems is depicted in Figure 083.3. The ore outlines (dotted lines) and zones of intense shearing (ruled pattern) are superimposed upon the major lithologies. All of the 2B Vein System, and part of the 12 Vein System, are characterized by sheeted networks of blue-grey quartz 'A' stringers, essentially identical to those observed at surface and throughout the mine. The stringers possess two distinct orientations, defined by the prevailing schistosity, either trending northwestly or westerly. Pyrite and chalcopyrite occur as grain aggregates along the veinlet margins, and presumably the gold is included with these, as in the surface occurrence. Flat white quartz plus anhydrite 'C' veins are commonly observed occupying subhorizontal joints.

The ore-hosting lithologies can best be described as alteration zones within a background altered sequence of fractured basalts. The dominant rock type is a variably carbonatized (ferroan dolomite) and anhydritized chloritic basalt (termed Chlorite Zone on Figure 083.3); this unit exhibits a very characteristic fracture pattern of interlocking conjugate fractures infilled with calcite-sugary pink anhydrite aggregates (termed "plymouth" rock in mine terminology). Broadly associated with the 2B orebody and the enclosing shear zones is a medium yellow-green sericite (phengite)-carbonate schist. Of significance is the localization of this unit along these strong shear zones, indicating a mineralogical and chemical transition in these rocks in response to the degree of deformation. Such profound differences between "background" chlorite zone volcanic rocks and these sericite-carbonate schists, would necessarily involve a focused fluid flow with a high fluid-to-rock ratio. A final alteration zone consists of pink-yellow, massive to granular quartz-hematite-albite-anhydrite-sericite rocks which occur along the northern edge of the 2B orebody. Rocks of this type are found throughout the mine, and have been termed "syenite", probably due to their red colour and massive nature. However, the gradational nature of the contacts with the chlorite zone, and the preservation of relict textures, would support a metasomatic origin for these rocks.

Turbiditic sedimentary rocks, consisting of finely laminated pyritiferous argillites intercalated with medium to coarse conglomerate (composed of volcanic and intrusive rock clasts), are in fault contact with the volcanic sequence, and, judging by the local bedding strike, are probably part of a faulted-in block. These rocks are possibly part of the Timiskaming sequence, which is common in the area southwest of the mine. A dark purple, heavily carbonatized biotite and "green" mica porphyroblastic dike (possibly lamprophyre) runs parallel to the dominant northwest-trending schistosity and is a late intrusive feature.

The most important structure on this level is the conjugate pattern of persistent, southerly dipping, shear zones of east-west to northwest-southeast orientation. These ductile shear zones clearly delimit the 2B stringer lode and account for the apparent stretching of the orebody to the northwest (a feature noted in the 2 Vein System with increasing depth, Troop 1985). A second order shear from the main 2B shear to the southeast may be responsible for localizing quartz stringer development and anomalous gold grades in the 2C area (Figure 083.3). Northwest-trending shears exhibit a strong cleavage in the same direction along which principal stringer development occurs; a strong secondary schistosity, striking easterly, is crenulated to a Z-geometry in plan view, indicating a sinistral sense of movement. Similarly, easterly trending shear zones bear an east-west cleavage, along which sheeted quartz stringers have developed with a northwest-trending schistosity, also rotated to a sinistral Z-geometry. The intersecting sheets of veinlets interfinger in orientations parallel to the principal shears.

THE 18 VEIN SYSTEM

Despite a location remote from the bulk of the Ross mineralization (*see* Figure 083.1), the 18 Vein System shares many similarities with the 2/2B stringer some 1000 feet (300 m) to the south. The 18 Vein area is also characterized by an intensely sheeted network of blue-grey quartz 'A' stringers. Lithogical mapping of the 18 Vein System on the 2850-foot level has revealed the most spectacular examples of alteration transitions from chlorite, to sericite, to hematite zones. Of particular interest here is the very high proportion of pink-brown "syenite" which hosts the ore, and the massive quantities of specular hematite and anhydrite present. Flat 'C' veins commonly occupy the subhorizontal joints and a large lamprophyre dike crosscuts the orebody from about the 2250-foot level down. The 18 Vein ore has generally produced 0.12 ounce gold per ton.

BRECCIA ORES

A previously undocumented mineralization type is here proposed for specific breccia vein lodes in the Ross Mine, most notably occurring in the 10/12 Vein System, the 13/14 Vein System, and probably the 1 Vein System. Recent mapping indicates that at least the lower portion of the 1 Vein System is a breccia similar to that seen in the 13/14 Vein System, and may have experienced left-lateral separation along a major north-south brittle fault (Figure 083.1). A major carbonate vein complex, which follows this fault, is intimately associated with the breccia ores on the upper levels, and especially in the 13/14 Vein area. The breccia lodes are the richest in the mine, with gold grades of up to 0.30 ounce per ton, and similarly high silver values.

THE 10/12 VEIN SYSTEM

The geology surrounding the 10 and 12 Vein Systems on the 2850-foot level is shown on Figure 083.3; their lateral separation from the 2B stringer lode is not great (several hundred feet) and these systems appear to coalesce with depth. The 12 Vein System is, in fact, largely a stringer lode in the western half while breccia ores are developed on the northeastern periphery. This transition is clearly visible on the 3000-foot and 3150-foot levels where mining development is currently in progress. These areas have afforded excellent exposures of the breccia ore type in both the 10 and 12 Veins. The breccia ores consist primarily of simple, mineralized, quartz-carbonate veins which have been fractured within a matrix of extensively milled and broken altered rock. It appears that the original narrow veins (or *en echelon* vein sets) have formed within the ductile deformation regime of intersecting northwestly and easterly trending shears. The veins are of the narrow 'B' type (Troop 1985), mineralized with massive bands and pods of galena-sphalerite-chalcopyrite and lesser tennantite. During a period of predominantly brittle deformation (manifested locally by north-trending faults) subsequent to vein formation, extensive brecciation and recementation of vein fragments has resulted in the breccia lodes; the ores are characterized by angular chunks of quartz-carbonate or sulphide mineralized vein material within a milled siliceous chloritic host rock. A weak northwesterly trending schistosity is present. The ductile shears have remained competent during the brittle deformation phase, but have been dragged in the plane of the major northeast-trending fault in a dextral sense.

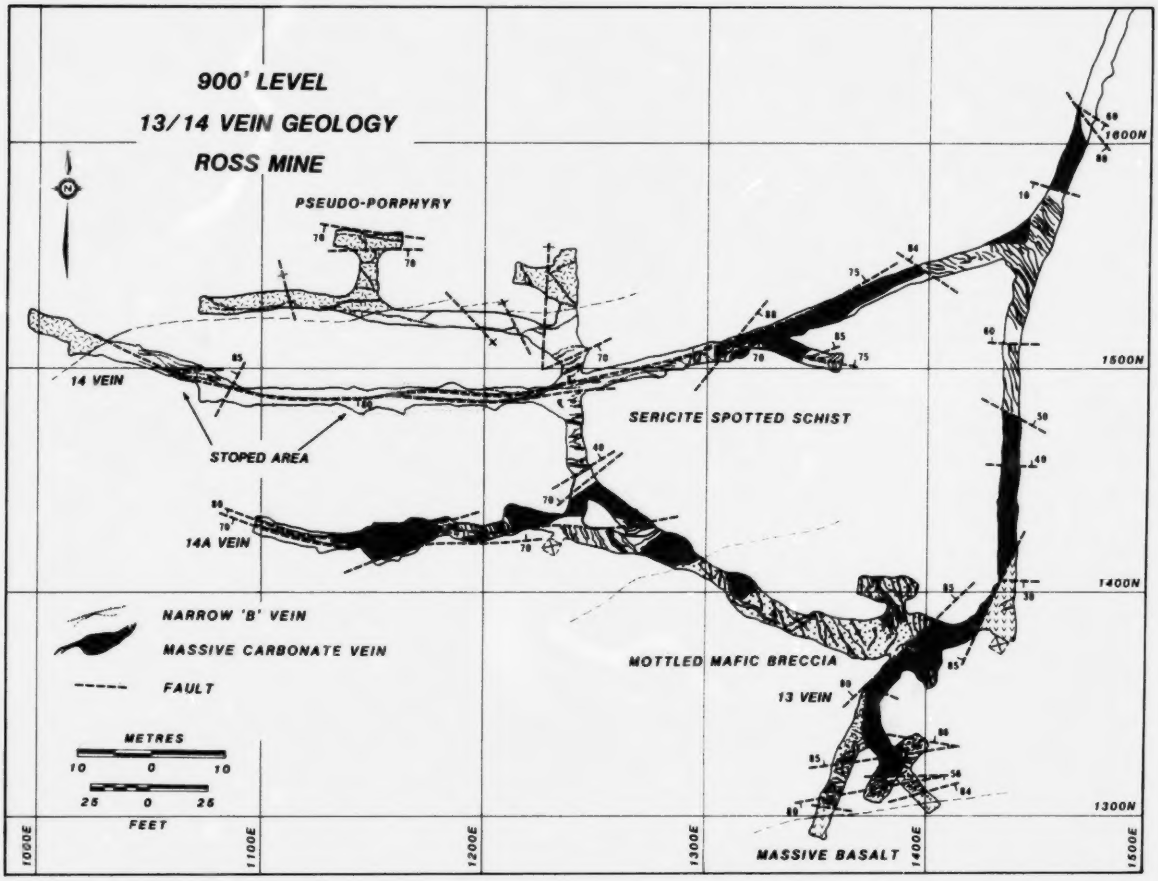


Figure 083.4. *Detailed plan geology of the 13/14 Vein System and vicinity on the 900-foot level from underground drift mapping. Geology of the actual 14 Vein drift (stoped and caved) is taken from archived Pamour (Hollinger) records.*

THE 13/14 VEIN SYSTEM

Extensive emplacement of a massive carbonate vein complex, and a myriad of different rock types not seen elsewhere in the mine, tend to add to the confusion to the geology of the 13/14 Vein area. Perhaps not surprisingly, it is the mineralized structures themselves which exhibit the greatest similarity with other parts of the mine and provide the evidence neccessary to interpret the geology of this area.

The detailed underground geology of the 13 and 14 Vein areas on the 900-foot level of the Ross Mine is presented in Figure 083.4, originally mapped at a scale of 1:240 (1 inch to 20 feet). The 13 Vein area in the southern portion of the map was mapped in 1985, and is now completely stoped and inaccessible. It is in this area, and in the 1050-foot sublevel approximately 75 feet below this, that the best breccia ores are observed. The 14 Vein is a simple narrow vein which has not suffered the degree of brittle deformation evident in the 13 Vein area.

The 13 Vein ore is composed of blocks of irregular, angular, white quartz-carbonate and galena-sphalerite-chalcopyrite fragments, which, before brecciation, probably resembled the now competent 14 Vein. Some banded disseminated pyrite is present in and around the fragments, and within the hosting coarse breccia. This lithology, the most consistently recognizable in the mine area, has been termed a mottled mafic breccia (Prest 1957). It is composed of dark green, irregular to somewhat elongate, pyrite-impregnated chlorite "fragments" within a siliceous green-grey matrix. The unit has a sharp southern contact with a schistose, chloritized basalt. The breccia is extensively and spectacularly veined, with white and salmon pink banded carbonate veins, ranging from several centimeters to more than 5 m across. It appears that the emplacement of this post-ore carbonate vein complex has occurred along a major north-south fault in areas of intense fracturing. Judging by the varying attitudes of these carbonate veins (from vertical to horizontal), it is suspected that they have intruded along most pre-existing planes of brittle failure.

North of the mottled mafic breccia, but still within the zone of intense carbonate veining, a yellow-green, schistose, predominantly sericite-carbonate unit is encountered. The unit is very characteristically spotted by light apple green pods and "fragments" of fuchsite (mariposite) impregnated with pyrite. It is possible that this unit may represent the highly altered equivalent of the mottled mafic breccia; however, a transitional zone confirming this has not been observed. Finally, north of the 14 Vein System is a unit called "pseudo-porphyry" in mine terminology, owing to a large proportion of tiny (1 mm) albite crystals set in a variably chloritic and siliceous matrix. The unit may well be a 'porphyry' in the intrusive sense, but only a detailed petrographic examination will confirm this.

NARROW VEIN ORES

Narrow vein ores, characterized by simple 'B' quartz-carbonate-sulphide veins (Troop 1985), were discovered essentially by accident at the Ross Mine during the early exploration drifting and diamond drilling around the 1 and 2 Vein Systems. These veins are fairly persistent in strike and dip extensions, but are located primarily from surface down to about the 1500-foot level. The distribution of narrow veins on the 450-foot level (Figure 083.1) reveals that most are found to the south and west of the 1 and 2 Vein Systems and strike consistently in a northwest-southeast orientation, essentially parallel to the prevailing host rock foliation. Mining of narrow veins at the Ross Mine has declined since the 1960s; a total of 184 317 ounces of gold was extracted from the 3, 4, 5, 6, 7, 8, and 15 veins at an average grade of 0.211 ounce per ton. Other narrow veins include the 9, 14, 16, 17, and 19 Veins. While silver production figures are not available, at least twice as many ounces of silver as gold were produced from these veins.

In contrast to the Au-Cu stringer ores, the metal character of the narrow veins is predominantly Ag-Au-Pb-Zn; sulphide pods and bands consisting of galena, sphalerite, and tennantite commonly occur within a massive white quartz vein with lesser white to pink carbonate. Akande (1982) reports silver sulphosalts, notably prousite (light ruby silver, Ag_3AsS_3), associated with the veins, while the author has observed visible creamy yellow-white gold (probable electrum) in 14 Vein samples. The veins tend to pinch and swell considerably, with widths ranging from about 20 cm to a metre; the hanging wall contact appears sharp along the controlling brittle shear, while a somewhat more diffuse and flexured contact with the wall rocks is exhibited on the footwall side. Host rocks surrounding the steep southwesterly dipping veins are generally moderately schistose parallel to principal vein orientation. Lithologies vary from massive basaltic volcanic rocks to altered and brecciated equivalents, but a thin discontinuous halo of sericitization is commonly observed mantling the vein margins. The geology of the 14 Vein on the 900-foot level is shown on Figure 083.4; this vein possesses many of the features common to narrow veins, although the orientation is more east-trending, probably as a result of rotational offset along the major north-south brittle fault that passes to the east of 14 vein.

ORE GENESIS AND DISCUSSION

Establishing a precise paragenetic sequence for the mineralization, alteration, and deformation events within the vicinity of the Ross Mine is a difficult task owing to the multiple styles of mineralization and to the evolution of the system over the explored vertical depth of the mine. In simplest terms, a change in deformational regime from predominantly ductile to predominantly brittle is observed with decreasing depth. This change can explain many of the observed differences in orebody and vein morphology. Similarly, an overall increase in the silver content of the brecciated and competent narrow veins is noted with decreasing depth, and this is probably related to the greater solubility of silver-bearing chloride complexes over gold-bearing thio complexes at elevated pressures and temperature. This premise assumes that the same mineralizing fluid carried both metals. The occurrence of hematite and anhydrite in shear zones and tension fractures at depth (below 1950 feet) indicates a prevailing high fO_2 during deformation and mineralization.

The temporal relationships of two sets of features in the mine are critical to an understanding of ore genesis and are perhaps somewhat controversial: a) the relative timing of the southeast- and east-trending ductile shear zones to brittle shear deformation, and b) the importance of prograde/retrograde metamorphism to the major deformational events. It is probable that a continued period of stress has given rise to a deep zone of ductile deformation which evolved upward into a zone of brittle fracturing; these fractures have provided a continuous favourable locus for fluid transfer and vein emplacement in the stringer lodes and narrow veins. A later, superimposed brittle event has been responsible for hydraulic fracturing of host rocks development of narrow veins to produce the breccia lodes. The problem of placing the regional metamorphism in context is more difficult to solve, since lower greenschist facies mineral assemblages are not terribly sensitive to prograde/retrograde events. It is suspected that the dominant southeast-trending foliation that is observed throughout the mine, represents the regional trend, and thus the southeast-trending shear zones may be contemporaneous with peak metamorphism. The potential for other orebodies of the type described in this report, either on the Ross property or the surrounding vicinity, is probably good, although any exploration excitement must be tempered with the realization that the targets are small in horizontal area. However, the real value of the Ross orebodies lies in their vertical persistence while maintaining a consistent grade. Both the stringer and breccia lodes demonstrate these features, making them attractive exploration targets. The discovery of the 18 stringer Vein System (Figure 083.1), far removed from the bulk of the Ross Mine workings, indicates the northward potential for these orebodies. Important features to be recognized in the definition of geologically favourable areas include:

1. intersecting strong cleavage and schistosity fabrics, possibly with blue-grey quartz stringer development
2. conjugate fracturing and brecciation

3. spatial association with iron-rich carbonate, sericite and hematite alteration

While southeast-trending linear structures seem to truncate to the east of the major north-trending fault system, these trends appear to continue to the northwest; thus, deep extensions of these structures are seen as prospective for additional ore. The narrow veins which occupy these structures on the upper levels are seen as less attractive exploration targets because of their limited width and confinement to the upper workings of the mine.

ACKNOWLEDGMENTS

Once again, the author would like to express his gratitude to the staff of Pamour Mines Incorporated, Ross Division, for enabling a great deal of work to be accomplished in a short span of time. The mine study was approved by Senol Eren, Chief Area Geologist, and underground guidance was provided by Paul Baleck, Mine Geologist.

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084. Black River-Matheson Economic Geologist Program

A.C. Bath

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INTRODUCTION

The position of Economic Geologist, in the office of the Kirkland Lake Resident Geologist, was established in May, 1984 as part of Operation Black River-Matheson (BRIM), a multidisciplinary geoscience program focused on a forty-township block located between Night Hawk Lake and the Ontario-Quebec boundary. Based in Kirkland Lake, the Economic Geologist is available to all members of the exploration community, at the local level, as a source of exploration-related information and advice. Efforts of the Economic Geologist are directed toward promoting exploration activity in the BRIM area and providing services which facilitate exploration. Specifically, the Economic Geologist is available to:

1. assist local prospectors with property visits, advice, and assessment file searches
2. document new mineral occurrences in the BRIM area and describe, more fully, known occurrences
3. compile available data relevant to exploration in the area
4. help orient those workers or potential workers who are new to the area

ACTIVITIES

Most of the 1986 field season was spent examining mineral showings within the BRIM area. Individual deposits examined during 1986 are located on Figure 084.1 and are briefly described in Table 084.1. More extensive descriptions of six of these properties appear below.

In keeping with the data compilation aspect of BRIM, updated versions of maps indicating: 1) collar locations of drill holes which are stored in the Larder Lake and Porcupine Mining Division Drill Core Storage Libraries, and 2) BRIM area Geological Data Inventory Folio status appear as Figures 084.2 and 084.3, respectively.

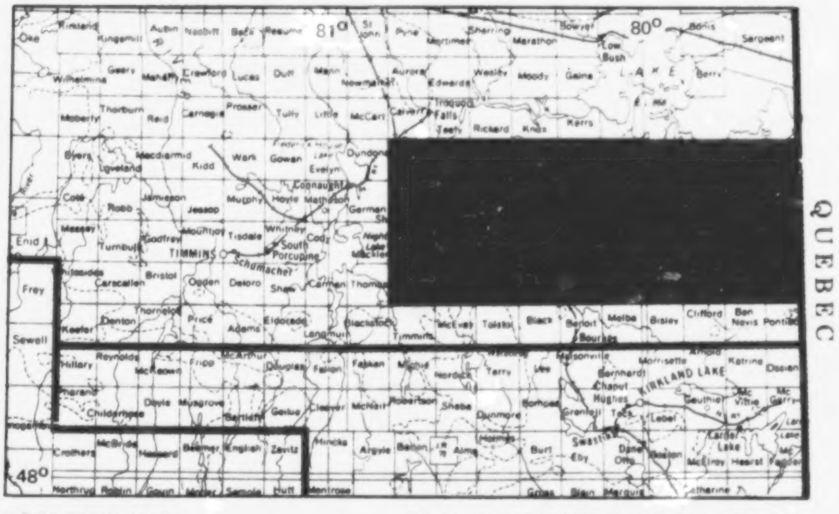
K.D. Kalicharran (Data Folio Geologist, Ontario Ministry of Northern Development and Mines, Kirkland Lake) represented BRIM and the Kirkland Lake Resident Geologist's Office, in Edmonton in early May at the Tenth Canadian Symposium on Remote Sensing by presenting a Remote Sensing poster display. Accepted for publication in the Symposium Volume was a paper by K.D. Kalicharran and A.C. Bath entitled "Application of Remote Sensing Data to Bedrock Geological Interpretation, Black River-Matheson Area, Northern Ontario, Canada".

A BRIM poster display was presented at the Matheson Fall Fair in August.

PROPERTY DESCRIPTIONS

BROWN-MUNRO OCCURRENCE, MUNRO TOWNSHIP

Pits, trenches, and shafts south of Croesus Lake in lot 2, concession II, Munro Township are located a short distance east of the paved road leading to the old Munro Asbestos Mine (Satterly 1952a). Access by foot to the showing area is provided by a northeast-trending, overgrown dirt road, accessible from the


81°
80°
48°
QUEBEC
TIMMINS
KIRKLAND LAKE
L A K E
Iroquois Falls
South Porcupine
Schumacher
Matheson
Larder Lake
Low Bush
Wilhelmina
Kingsmill
Aurora
Mortimer
Marathon
Sergeant
Geary
Crawford
Lucas
Duff
Mann
Newmarket
Edwards
Wesley
Moody
Gains
Berry
Moberly
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Teefy
Richard
Knox
Kerrs
Byers
Macdiarmid
Loveland
Kidd
Wark
Gowan
Evelyn
Dundonald
Connaught
Cote
Robb
Jamieson
Jessop
Murphy
Hoyle
German
Massey
Godfrey
Mountjoy
Tisdale
Whitney
Cody
Night Hawk Lake
Enid
Turnbull
Frey
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Keefer
Denton
Thorneloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
Tolstoi
Black
Benoit
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Sewell
Reynolds
Hillary
McKeown
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Maisonville
Morrisette
Katrine
Bernhardt
Chaput Hughes
Gauthier
McVittie
McGarry
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Grenfell
Teck
Lebel
Childerhose
Crothers
McBride
Hassard
Beemer
English
Zavitz
Mincke
Argyle
Belton
Alma
Burt
Eby
Otto
Swastika
McElroy
Hearst
Northrup
Montrose
Catherine

LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles

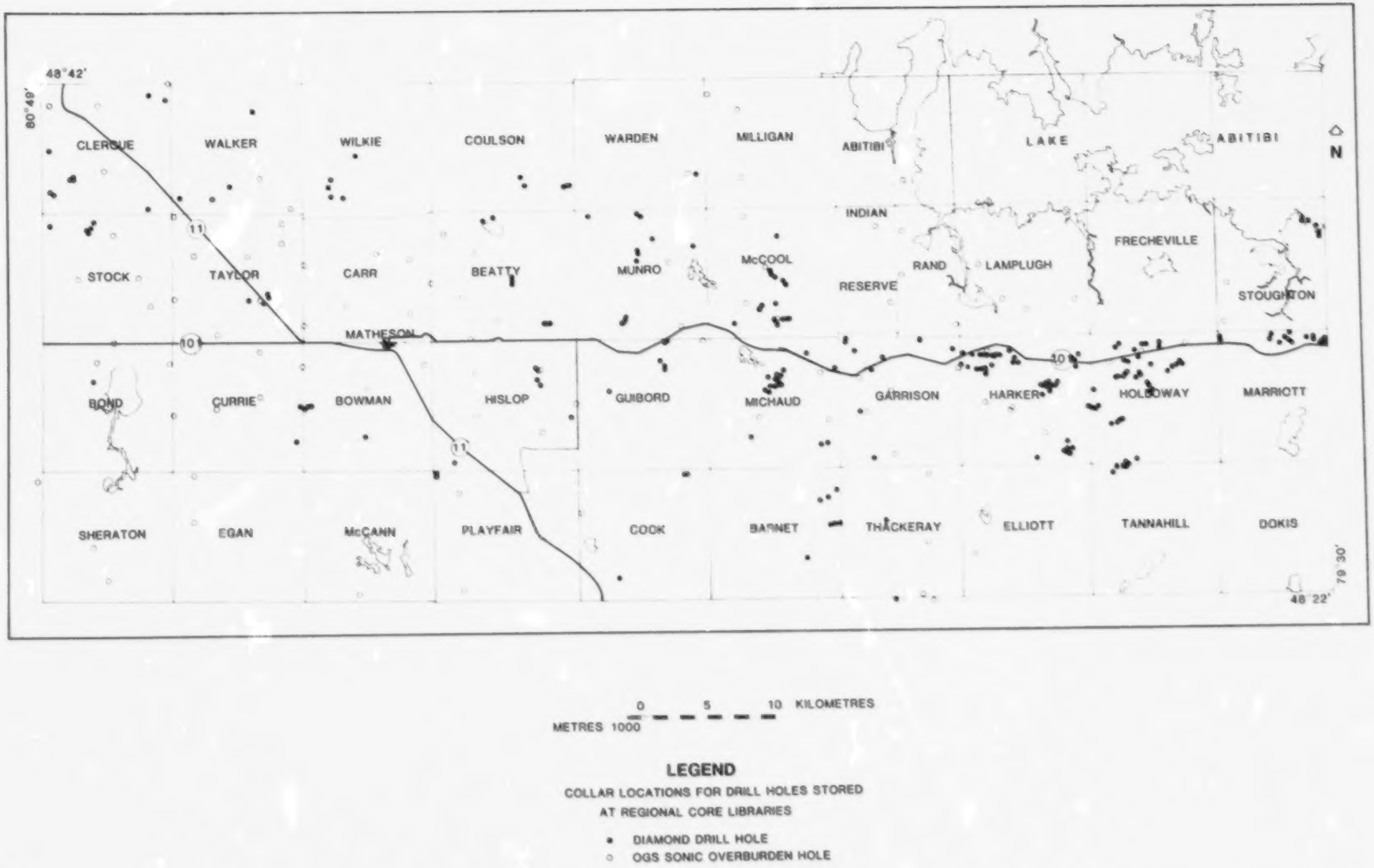

48°42'
80°49'
CLERGUE
WALKER
WILKIE
COULSON
WARDEN
MILLIGAN
ABITIBI
LAKE
ABITIBI
N
INDIAN
STOCK
TAYLOR
CARR
BEATTY
MUNRO
McCOOL
RESERVE
RAND
LAMPLUGH
FRECHEVILLE
STOUGHTON
11
10
MATHESON
10
BOND
CURRIE
BOWMAN
HISLOP
GUIBORD
MICHAUD
GARRISON
HARKER
HOLLOWAY
MARRIOTT
11
SHERATON
EGAN
McCANN
PLAYFAIR
COOK
BARNET
THACKERAY
ELLIOTT
TANNAHILL
DOKIS
79°30'
48°22'
0
5
10
KILOMETRES
METRES 1000
LEGEND
COLLAR LOCATIONS FOR DRILL HOLES STORED
AT REGIONAL CORE LIBRARIES
● DIAMOND DRILL HOLE
○ OGS SONIC OVERBURDEN HOLE

Figure 084.1. *1986 property visits, Black River-Matheson Economic Geologist. Map numbers used are identical to those used in Bath (1985, Figure 084.2).*

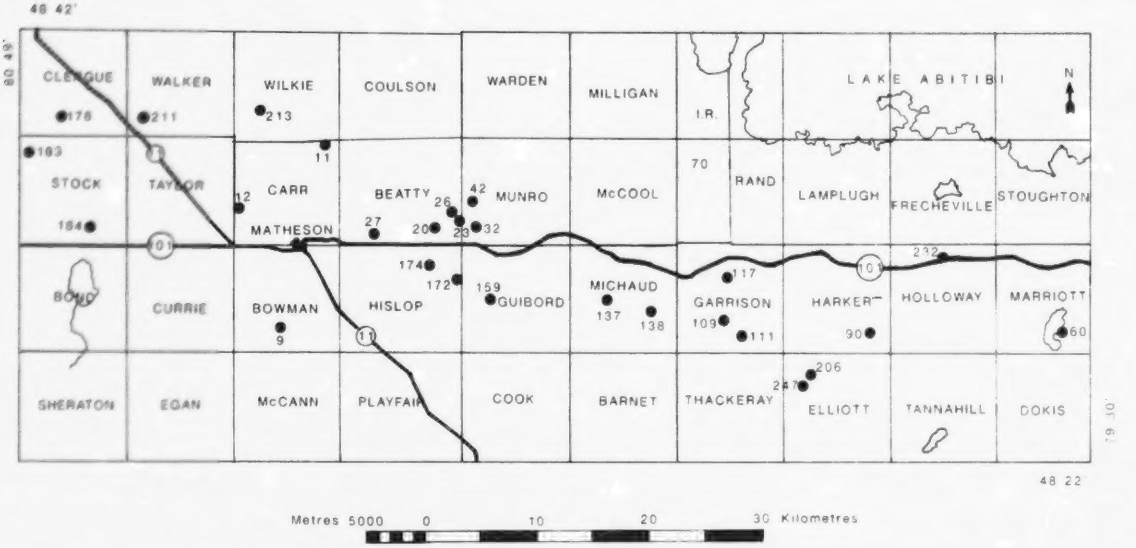

48 42'
80 49'
CLERGUE
WALKER
WILKIE
COULSON
WARDEN
MILLIGAN
I.R.
LAKE ABITIBI
N
178
211
213
183
11
STOCK
TAYLOR
12
CARR
BEATTY
26
42
MUNRO
McCOOL
70
RAND
LAMPLUGH
FRECHEVILLE
STOUGHTON
184
MATHESON
27
20
23
32
101
174
172
159
232
117
BOND
CURRIE
BOWMAN
HISLOP
GUIBORD
MICHAUD
137
138
GARRISON
109
111
HARKER
90
HOLLOWAY
MARRIOTT
60
9
11
206
247
SHERATON
EGAN
McCANN
PLAYFAIR
COOK
BARNET
THACKERAY
ELLIOTT
TANNAHILL
DOKIS
79 30'
48 22'
Metres 5000 0 10 20 30 Kilometres

Figure 084.2. Drill hole collar location map for BRIM area core stored in the Larder Lake and Porcupine Mining Division Drill Core Storage Libraries.

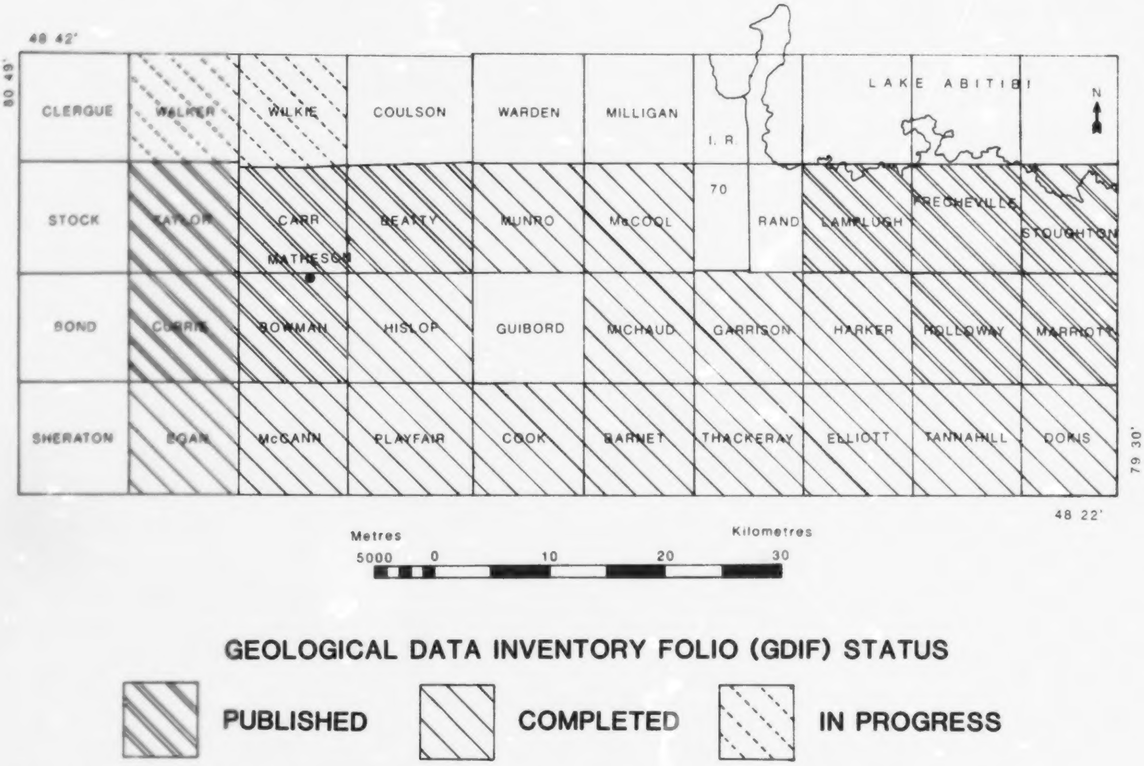

48 42'
80 49'
CLERGUE
WALKER
WILKIE
COULSON
WARDEN
MILLIGAN
I. R.
LAKE ABITIBI
N
70
STOCK
TAYLOR
CARR
BEATTY
MUNRO
McCOOL
RAND
LAMPLUGH
FRECHEVILLE
STOUGHTON
MATHESON
BOND
CURRIE
BOWMAN
HISLOP
GUIBORD
MICHAUD
GARRISON
HARKER
HOLLOWAY
MARRIOTT
SHERATON
EGAN
McCANN
PLAYFAIR
COOK
BARNET
THACKERAY
ELLIOTT
TANNAHILL
DOKIS
79 30'
48 22'
Metres
5000 0 10 20 30
Kilometres
GEOLOGICAL DATA INVENTORY FOLIO (GDIF) STATUS
PUBLISHED
COMPLETED
IN PROGRESS

Figure 084.3. BRIM area GDIF status.

Munro Mine road via a rotting, wooden bridge that crosses a 2 to 3m wide, water-filled ditch.

The workings are located within 120°-trending, north-facing and subvertical to north-dipping

TABLE 084.1: SUMMARY OF MINERAL SHOWINGS VISITED DURING 1986 BY THE BLACK RIVER–MATHESON ECONOMIC GEOLOGIST. NUMBERS REFER TO LOCALITIES ON FIGURE 1.

Property Name	Commodity	Lithology/ Host Rock	Alteration/ Gangue	Ore Minerals
9. Pollock-Briscoe	Au	K.i	carb	py,po
11. Wilcarr	Au	SR,mv or uv	qtz,carb	asp,py,cp
12. Watabeag	Au	SRG,mv	qtz,carb	"sulfides"
20. Stewart-Abate	Au	P.s,d	qtz.carb.ser,tour	py,co,cp,mo,Au
23. Denovo	Au	P.lamp	ser,carb,qtz	py,cp,asp
26. Pat	Au	SR,mv	carb,ser,sil	py
27. J.A. Rhodes	Au	SR,d	qtz,carb,hm	py,cp,azur
32. Brown-Munro	Au	SR,mv	qtz,carb,tour	asp,py,cp,sph,bn
42. Northern Gold Belt	Au	SR,fv	qtz,ser,carb	py,asp
60. G.C. Roy	Au	BR,mv,iv	ep,sil(?)	py,cp
90. Golden Harker	Au	K,mv,i	hm,carb,sil,qtz	py
109. Murphy	Au	K,mv	carb,sil,hm,qtz	py
111. Deloye	Au	K,i	carb,sil,ser,qtz	py
117. Hastings	Au	P.s.lamp	ser,hm(?),sil,qtz	py,gal,cp
137. Michaud-Porcupine	Au	fi	qtz	py,mo
138. Miller	Au	SR,s,carb	qtz,carb,ser,tour	py
159. Caman	Au	SR,carb	carb,ser,qtz	py,gal,cp,Au
172. Hislop Mines	Au	SR,mv,uv	carb,tour,qtz	py,cp,Au
174. Abuy GML	Au	SR,mv	carb,qtz	py,cp
178. Monclerg ML	Au	SR,fv,i	qtz,carb	py,asp
183. Clavos	Au	SR/P.mv.uv.s,i	qtz,carb,ser	py,asp,cp
184. St. Andrew Goldfields	Au	Sr,mv	carb,ser,hm,qtz,sil	py,cp,asp,Au
206. Ghost Lake	Au	K,fv,i,fi	carb,hm(?)	py
211. Silver Foam	Au	SR,mv,fv,iv	qtz,carb,ep,asb	py
213. Noran	Au,Cu	SR,fv,i	qtz,carb,ser	py,cp,gal,sph
232. Canamax East Zone	Au	SR/P,mv,uv,s	qtz,carb,ser	py,asp,Au
247. T. Randa	Au	K,mv,i	carb	py

BR - Blake River Group
HM - Hunter Mine Group
K - Kinojevis Group
P - Porcupine Group
SR - Stoughton-Roquemaure Group

d - diorite
fi - felsic intrusive rock
fv - felsic volcanic rock
i - interflow sediment or tuff
iv - intermediate volcanic
lamp - lamprophyre
uv - ultramafic volcanic rock

asb - asbestos
asp - arsenopyrite
azur - azurite
bn - bornite
carb - carbonate
cp - chalcopyrite
ep - epidote
gal - galena
hm - hematite
mo - molybdenite
po - pyrrhotite
py - pyrite
sph - sphalerite

tholeiitic, pillowed, and variolitic basaltic rocks of the Stoughton-Roquemaure Group. All showings examined are located within about 500 m of the Contact Fault, a locus of sericitization and carbonatization which in this area trends approximately 120°, dips steeply, and separates north-facing Stoughton-Roquemaure Group volcanic rocks to the northeast from a wedge of north-facing, dominantly turbiditic sedimentary rocks of the Porcupine Group to the southwest (Johnstone and Trowell 1985a, 1985b, Satterly 1952a). Intrusive rocks present in the area include quartz diabase dikes of the Matachewan swarm and late stage lamprophyre dikes. The workings are located in an area that hosts numerous northeast- to north-northeast-trending cross faults and several north- to northeast-trending vein systems, the best known of which is the Munro-Croesus; a high grade, low-tonnage quartz vein deposit that yielded 14 854 ounces (462 004 g) of gold and 1423 ounces (44 260 g) of silver from 5333 tons of grey quartz-pyrite-arsenopyrite ore milled (Satterly 1952a). A recent airborne geophysical survey of the area (OGS 1984c) did not indicate any anomalous airborne electromagnetic (AEM) conductors associated with the showings.

The No.1 shaft was sunk into light green, fine to medium-grained, pillowed and hyaloclastic basalt, about 50 m northeast of quartz-veined basalt exposed by pits. The quartz-carbonate vein, on which the shaft was sunk, is buried under broken rock and is not exposed. Dump material consists of light grey to buff coloured, medium grained, nonmagnetic, carbonatized basalt, which is cut by clear, glassy, grey and white quartz, and quartz-carbonate vein material containing rare, fine grained, acicular, and massive aggregates of black tourmaline. Scant disseminated pyrite, chalcopyrite, bornite, and honey-colored sphalerite occur within, and externally to, quartz veinlets.

Dump material present at the site of the No.2 shaft consists of rusty weathering carbonate plus quartz vein material with sparse, very fine grained pyrite, and barrel-shaped arsenopyrite occurring both within vein material and within locally carbonatized basalt hosting the veins. The No.2 shaft was probably sunk on the northeastern extension of a 060°-

trending, 50 to 180 cm wide, quartz-carbonate vein, which was exposed by trenching and pitting from the shaft continuously for about 170 m to the southwest. This vein carries sparse pyrite and arsenopyrite mineralization at various locations along its exposed length and is accompanied by local carbonatization of the basalts by which it is hosted.

The No.4 shaft is closest to the paved road lying to the west, and is sunk into carbonatized, variolitic lavas; the shaft was covered with waste rock when visited. Dump material consists of variably silicic, variolitic lavas, carbonatized, aphanitic felsite composed of partly to completely coalesced, leucocratic, variolitic domains within basalt, and minor clastic interflow sedimentary rocks, all of which may be brecciated or cut by white calcite or calcite+quartz veins. Vein material may be mineralized with sparse, fine-grained pyrite and acicular arsenopyrite. More commonly, up to 6 percent combined pyrite and arsenopyrite occur within carbonatized wall rock adjacent to, or as wall rock xenoliths contained within vein material. Laboratory analysis of samples collected during the field season confirmed the report by Satterly (1952a) of well mineralized material assaying up to 0.30 ounce gold per ton (10.3 g/t).

DENOVO OCCURRENCE, BEATTY TOWNSHIP

Two shafts are located in the southeast quarter of the south half of lot 1, concession II, Beatty Township with access provided to within about 50 m of the site via an overgrown road (passable by all-terrain vehicle) accessible from the paved road leading to the old Munro Asbestos Mine in Munro Township, as indicated by Satterly (1952a) and Satterly and Armstrong (1949).

Satterly and Armstrong (1949) indicate that the northern shaft was sunk vertically 9.7 m (32 feet) into a 60 to 150 cm (2 to 5 feet) wide carbonatized lamprophyre sill that is host to unmineralized quartz-carbonate stringers, and that intrudes "mashed", interbedded, 108°-striking and moderately to steeply south-dipping quartzites and greywackes, of the Porcupine Group, about 50 m southwest of the Contact Fault. The southern shaft is located about 230 m east-southeast of the first shaft, and is accessible, by foot, via a very badly overgrown road which may be located where it crosses the Munro-Beatty Township boundary. The shaft was sunk in carbonatized, and locally pyritic, Porcupine Group quartzites, which trend 102 to 105° and dip 80° to 87°S, and which host quartz-carbonate stringers and a few narrow feldspar-porphyry dikes (indicated from drilling). About 1500 m to the west-northwest, a locally carbonatized quartz porphyry is present within the Porcupine Group sedimentary rocks adjacent to the Contact Fault. A small body of locally sericitized and carbonatized feldspar porphyry is indicated (Satterly and Armstrong 1949) to occur within the sedimentary rocks about 1800 m to the southwest of the showings. Late stage lamprophyre dikes, trending both parallel and transverse to local stratigraphy, are present in the area, and no anomalous AEM conductors are indicated to be associated with the showings (OGS 1984b).

The northern shaft was open (not capped), measured 4 by 3 m at surface, and was flooded in June of 1986. Broken rock observed in a rock pile adjacent to the shaft contained coarse to very coarse grained, clear, glassy, quartz, rimmed by white quartz, and brown-weathering carbonate+quartz vein material cutting hard, rusty-weathering carbonatized lamprophyre dike material which contained 30 mm clots of emerald-green fuchsite (after biotite phenocrysts). Interbedded, fine-grained, carbonatized, and sericitized quartzite and greywacke, present in the rock pile, were devoid of vein material. Scant, very fine grained pyrite cubes were observed in the sedimentary rocks and the carbonatized lamprophyre; coarse grained pyrite was observed in clear, glassy vein material only once.

The southern shaft was surrounded by prominent piles of waste rock, attesting to significantly more underground exploration work than the 8.5 m (28 feet) depth excavated for a two-compartment shaft (as indicated by Satterly and Armstrong 1949). Waste rock consists of thickly bedded sandstones with minor interbeds of graded argillites. Mineralization observed in the waste piles included pyrite and arsenopyrite associated with white carbonate+quartz gash veins. Associated sericite and carbonate alteration is developed preferentially in brittlely fractured sandy horizons, rather than in finer grained, generally sheared and sericitic argillitic interbeds.

PAT OCCURRENCE, BEATTY TOWNSHIP

Pits, trenches, and overgrown outcrop stripping are located in the south half of the north half of lot 1, concession II, Beatty Township. Access to within about 300 m of the showing area is provided by a foot trail trending northeast from the Beatty-Munro Township boundary, and which is accessible by ATV from the paved road to the Munro Asbestos Mine in Munro Township, as indicated by Satterly (1952a) and Satterly and Armstrong (1949). The remaining distance must be covered on foot through relatively open bush.

The showing is located within 098° to 114°-trending, north-facing, and generally north-dipping, pillowed and variolitic tholeiitic basalts of the Stoughton-Roquemaure Group, approximately 200 m northeast of the 125°-trending Contact Fault. The Contact Fault separates dominantly turbiditic sedimentary rocks of the Porcupine Group to the southwest from the dominantly komatiitic Stoughton-Roquemaure volcanic rocks to the northeast (Johnstone and Trowell 1985a, 1985b, 1984). A northeast-trending quartz diabase dike of the Abitibi swarm is present about 600 m northwest of the showing, and a small intrusive body of locally carbonatized quartz porphyry occurs about 1200 m to the west-southwest and is apparently confined to the sedimentary rocks, south of the Contact Fault. Late stage lamprophyre dikes with various orientations are also present in the vicinity of the showing. A recent airborne survey of the area (OGS 1984b) did not indicate any anomalous AEM conductors associated with the showing.

Mineralization observed consisted of narrow, rusty, and recessively weathering pyritic seams developed in variolitic basalt. These well exposed, northeast-trending seams crosscut local stratigraphy, and have been explored by pits and trenches. They are of unknown origin. Also exposed, though poorly so, in overgrown pits and trenches, east of the pyritic seams, are silicic, carbonatized, sericitized, and pyritic variolitic lavas of unknown extent. Satterly and Armstrong (1949) indicate that these altered variolitic lavas are associated with a north-trending brecciated zone which, on the basis of drilling data and outcrop/stripping exposure no longer in evidence, was interpreted to be no more than about 15 m across. The presence of anomalous gold assay values, reported by these authors to be associated with both types of mineralization, was confirmed by the writer.

POLLOCK-BRISCOE OCCURRENCE, BOWMAN TOWNSHIP

The showing is located in lot 7, concession II in Bowman Township, and is indicated by Leahy (1965) to consist of copper mineralization. Access to within about 250 m of the showing may be made by a two-wheel drive vehicle via an east-west road located south of the showing; the remaining distance must be covered on foot through relatively open bush.

Pits are located near the north edge of an outcrop exposing 113°-trending, south-facing, and subvertically dipping, medium- to coarse-grained basalt flows of the Kinojevis Group. A conformable, porphyritic unit, stratigraphically overlying and to the southwest of these basalts, is well exposed a few tens of metres southwest of the pits. It has been mapped by Jensen (1985a) as a calc-alkalic crystal tuff. Another possibility is that this is detritus eroded from a subaerially exposed calc-alkalic terrain. The showing is located about 180 m east of a 173°-trending Matachewan quartz diabase dike and about 1,000 m north of the exposed contact of a large, monzonitic, intrusive body. A recent airborne electromagnetic (AEM) survey did not reveal any anomalous conductors associated with the pit area (OGS 1984a).

Mineralization consists of pyrite and pyrrhotite associated with a friable, rusty weathering, 1 m thick, 100°-trending and 54°N-dipping, chloritic schist. This schist is in sharp contact with overlying, fine grained, magnetic, incipiently sheared, leucoxene-bearing basalts to the southwest.

Angular, brecciated pyrrhotite and fine-grained, disseminated to 2 cm idioblastic pyrite occur within the schist and within an undulose, marginal, magnetic, less intensely sheared, 25 to 35 cm wide zone of carbonatized, leucoxene-bearing basalt. The presence of minor cherty (sedimentary) horizons within the schist indicates that this shear zone was developed primarily within an interflow horizon of mafic, and probably sulfide-bearing, sedimentary rocks and/or tuffs with only minor shearing developed within the marginal, leucoxene-bearing basalt flow. Shearing resulted in recrystallization of the sedimentary sulphide component, and provided access for late stage hydrothermal solutions which caused local carbonatization of marginal, less intensely sheared, basalt and deposition of pink calcite as late stage veins and also as blebs developed in the shear zone and, in places, in the unsheared basalts.

STEWART-ABATE OCCURRENCE, BEATTY TOWNSHIP

The showing is located in the north half of lot 5, concession I, Beatty Township with access provided from Highway 101 (from the south) via a dirt road suitable for all-terrain vehicles (ATVs). The showing is located about 1200 m north of Highway 101.

The showing is indicated by Satterly and Armstrong (1949) to consist of a fault-controlled, auriferous quartz-carbonate vein. The fault hosting the main vein is reported to strike 070° and cut sericitized, carbonatized, and irregularly pyritized Porcupine Group sedimentary rocks, which trend 095° to 135° and dip 65° to 80°S, and a 61 m thick dioritic sill. Where the fault zone cuts the sill, it is described as being 1 to 3 m wide, composed of carbonatized diorite, and is host to a 15 to 45 cm wide, rusty weathering, quartz-carbonate vein that is sparsely mineralized with pyrite, pyrrhotite, chalcopyrite, and, rarely, visible gold and molybdenite. Development work performed prior to 1941 included a 37 m (122 feet) deep, two-compartment inclined shaft. At the 20 m (65 feet) level, 64 m (210 feet) of drifting established: a) the presence of a zone grading 0.31 ounce gold per ton (10.6 g/tonne) across 1.2 m (4 feet) along a length of 55 m (180 feet) on the 20 m level; and b) that the auriferous vein material was apparently confined exclusively to that length of the fault zone that intersected the sill (Satterly and Armstrong 1949).

The workings are located about 300 m southwest of a variably carbonatized and sericitized feldspar porphyritic intrusive body in an area host to late stage lamprophyre dikes oriented at various angles to the local stratigraphy. No anomalous AEM conductors were identified by a recent geophysical survey (OGS 1984b) as being associated with the property.

Visible on surface is the capped shaft, piles of broken rock, and extensive pitting and trenching, which follow a 2 m wide shear zone developed in a medium-grained, locally carbonatized gabbro or diorite. Dump material consists mainly of moderately well foliated, sericitized, and carbonatized diorite with lesser amounts of broken vein material. Vein material consists of: a) coarse grained, milky white quartz; b) greasy-looking white to grey quartz; and c) rusty weathering, 2 to 30 mm wide, fine- to coarse-grained carbonate veinlets that cut the (earlier) quartz veins. Pyrite, up to 2 percent molybdenite, and (rarely) black tourmaline occur within the quartz vein material, with pyrite and molybdenite occurring as flecks and seams within altered diorite as well as within the quartz veins.

DELOYE OCCURRENCE, GARRISON TOWNSHIP

An overgrown and poorly exposed trench, excavated into altered interflow sedimentary rocks of the Kinojevis Group, is located south of the common boundary between patented mining claims L 39255 and L 40088 in south central Garrison Township, about 280 m south of the southern intrusive contact of the Garrison stock (Satterly 1949). Access to within about 700 m of the trench is provided by a road accessible from Kerr Addison's Murphy-Garrison Open-Pit Mine. This road is passable by means of a four-wheel-drive truck; the remaining distance must be covered on foot along overgrown roads and across recently logged bush.

The poorly exposed trench reveals grey to grey-green to mauve, variably silicic (cherty) and pyritic, fine-grained, and, where relatively unaltered, finely laminated, interflow siltstones and chemical sedimentary rocks. The sedimentary rocks are often fractured at the 1 to 5 mm scale. Multiple sets of these fractures have developed around prominent carbonate-sericite-(silica?) alteration that gives the rock a stockwork appearance. Late stage quartz-carbonate veinlets cut the earlier fractures and in places are brecciated. Very fine grained secondary pyrite occurs along crosscutting fractures as well as along what appear to be primary laminations. Five grab samples from the trench, analyzed by Accurassay Laboratories Limited of Kirkland Lake, contained 9, 15, 26, 63 and 115 ppb Au, respectively.

The trench is in an area of poor outcrop exposure about 650 m west of a major 170°-trending fault that cuts the Garrison stock to the north. The exposed sedimentary rocks are located immediately north of the axis of a prominent, continuous, regional magnetic "valley". The "valley" parallels the Kinojevis Group stratigraphy and, east of the showing, trends 058°, gradually assuming a 080° orientation as it passes immediately north of Ore Car Lake and continues to the west (OGS 1984d). Immediately west of, and approximately along strike from, the trench, a continuous 4 800 m conductive horizon (as defined by anomalous 1 to 5 channel AEM INPUT® responses on 25 contiguous flight lines) is indicated to be present (OGS 1984d). As part of the 1985 BRIM sonic overburden drilling program, hole number 85-26 was drilled northwest of Ore Car Lake, approximately 1400 m southwest along strike from sedimentary rocks exposed in the trench. After encountering 34.4 m of glacial overburden, including a section of till that was sampled from a depth of 34.1 to 34.4 m and that yielded no gold grains, according to Baker *et al.* (1986), the hole was stopped in bedrock. Bedrock consists of black, fine-grained, nonmagnetic,pyritic, cherty interflow siltstone (Jensen and Baker 1986). Anomalously high gold-grain counts were obtained from one backhoe till sampling site approximately overlying the magnetic "valley" (sample site 85-076-B), and from two sites located a short distance south of (down ice from) that part of the magnetic "valley" with the coincident AEM conducter (sample sites 85-077-B and 85-078-B). All three sampling sites contained delicate gold grains, indicating glacial transport distances of less than 100 m (Steele *et al.* 1986).

ADVICE TO PROSPECTORS

Historically, exploration for gold has been concentrated along both the Porcupine-Destor and Pipestone Fault Zones within which auriferous quartz-carbonate veins and stringers typically are hosted by various carbonate-, sericite-, chlorite-, talc-, and serpentine-bearing schists. Gold occurs both in the native state and associated with pyrite. Other associated ore minerals are arsenopyrite, chalcopyrite, and galena (Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Kirkland Lake); examples of this type of mineralization occur at the Canamax (Clavos), St. Andrew Goldfields, and Canamax (East Zone) properties. Similarly, much activity has been directed towards discovering and developing auriferous quartz-carbonate vein systems associated with intrusive felsic stocks. Such mineralization occurs both internally and externally to the associated felsic intrusive body, and may be accompanied by silicification, pyritization, carbonatization, and/or hematization (Cherry 1982). Examples of this type of mineralization include the Canadian Arrow deposit and the Murphy-Garrison deposit, and may also include the Esso Minerals/Quebec Sturgeon River Porphyry Zone in Taylor Township. Continued exploration for both types of mineralization is still warranted.

In addition to the Porcupine-Destor Fault (the location of which in Guibord and Michaud townships has been slightly reinterpreted (Jensen 1985) and the Pipestone Fault Zones, gold, and possibly base metal mineralization, exists associated with both the north and south, faulted contacts between Porcupine Group sedimentary rocks and Stoughton-Roquemaure Group volcanic rocks within Munro, Beatty, and Hislop Townships. Although to the east in Guibord Township, the Porcupine/Stoughton-Roquemaure contact appears to be conformable (Johnstone and Trowell 1985b), to the west, in Munro and Beatty Townships,"...the faulted contact between the volcanic rocks and the sedimentary rocks is characterized by a lens of intense carbonatization containing quartz-carbonate veins..." (Johnstone and Trowell 1985b, p.292). The extensions of these fault zones to the west, prior to their merging with the Porcupine-Destor Fault Zone to the south and the Pipestone Fault Zone to the north, are largely overburden covered and poorly known (Johnstone and Trowell 1985a). Such areas merit a closer look (but cf. Satterly and Armstrong 1949, p.17 to 18).

The potential of the Porcupine Group sedimentary rocks, as well as the grossly subparallel zone of felsic volcanics to the south, to host auriferous vein systems, associated with felsic intrusive bodies, has not yet been adequately investigated.

Recent encouraging results on the American Barrick Resources Corporation "McDermott" and adjoining claim groups prompted their sinking a shaft, now near completion. Barrick's discovery has resulted in substantial exploration activity for similar gold mineralization elsewhere in the BRIM area. McDermott-type mineralization consists of native gold within and on pyrite (A.W. Workman, Project Geologist, American Barrick Resources Corporation, personal communication, 1985), which occurs within pods hosted by pale purple, hematitic, pyritic, carbonatized, and silicic rocks of controversial origin.

Historically, the host rocks have been variously described as silicified basalt, rhyolite, and felsitized andesite (Resident Geologist's Files, Ontario Ministry of Northern Development and Mines, Kirkland Lake). More recently, a sedimentary origin for the mineralized zone has been suggested (H. Lovell, Resident Geologist, Ontario Ministry of Northern Development and Mines, Kirkland Lake). The deposit's country rocks are tholeiitic basalts of the Kinojevis Group, as indicated by Jensen (1982a). Regional, east-northeast-trending faults transect the deposit area, and the Porcupine-Destor Fault Zone is located a short distance north of the McDermott and Mattawasaga discoveries. American Barrick Resources Corporation has established the presence of mineralization in this gold-bearing zone, over a strike length of several kilometres, by diamond drilling in an area of little outcrop exposure. The anomalous zone coincides with a broad magnetic low of regional extent.

Much of the bedrock geology underlying the BRIM area south of the Porcupine-Destor Fault Zone is of low metamorphic rank, dominantly tholeiitic Kinojevis Group volcanic rocks and interbedded sedimentary rocks (MERQ-OGS 1983). The Kinojevis Group is characterized by well defined magnetic stratigraphy consisting of alternating bands of magnetic highs and lows (OGS 1984). The stratigraphy of the Kinojevis Group, as elucidated by airborne magnetic data, may be traced more or less continuously over strike distances of 75 km with only minor disruptions due to cross-faulting or the intrusion of felsic stocks. In the Harker-Holloway townships area, there are multiple, discrete horizons of what have been variously interpreted as (meta) tuff, chert breccia, cherty tuff, dacite, rhyolite, partially silicified or carbonatized mafic volcanic rocks, and fault zones (Jensen 1982a, 1982b, Satterly 1952b, 1954). Most of these rocks contain pyrite and anomalous gold values at various places along their strike, typically associated with discrete magnetic lows of regional extent.

Much of the exploration work currently taking place in the southeast-central BRIM area is being focused along these horizons and their strike extensions, as elucidated by the Kinojevis Group magnetic signature, in hope of discovering mineralization analogous to that already delineated by American Barrick Resources Corporation. Should these hopes be borne out, the apparent continuity of Kinojevis Group stratigraphy south of the Porcupine-Destor Fault Zone indicates that analogous mineralization could be expected to occur to the west along strike. Mineralization analogous to that found in the Holloway-Harker area may also occur north of the Porcupine-Destor Fault Zone within Kinojevis Group rocks underlying parts of Stoughton and Frecheville townships. Described as occurring here, especially in the lower 1000 m of the Kinojevis Group stratigraphic section, are felsic and sedimentary rocks such as "...interflow units of tuff-breccia, crystal tuff and cherty tuff of calc-alkalic dacite and rhyolite composition, as well as chert, argillite, graphite, and cherty oxide iron formation" (Jensen and Langford 1983, p.234).

Calc-alkalic rocks of the Hunter Mine Group, which underlie major portions of Walker, Wilkie, Coulson, Warden, Milligan, McCool, Rand, Lamplugh, and Frecheville Townships, and the Blake River Group, which underlies major portions of Marriott, Dokis, Tannahill, and Elliot Townships (MERQ-OGS 1983), are potentially host to volcanogenic Pb-Zn-Cu-Au-Ag sulphide mineralization.

Komatiitic Stoughton-Roquemaure Group volcanic rocks underlie much of the central and northwestern BRIM area, and are potentially host to nickel sulphide mineralization and to industrial minerals including asbestos, serpentine bulk filler, magnesite, and talc. The Hedman Mine in southern Warden Township is a serpentine deposit currently in production (Whittaker and Malczak 1984).

The potential for komatiitic Stoughton-Roquemaure Group volcanic and intrusive rocks and for discordant gabbroic and ultramafic intrusive bodies described to be present in the central BRIM area (Johnstone and Trowell 1985b) to host platinum group elements has yet to be evaluated.

Kimberlite dikes in Michaud Township (Jensen 1975) and kimberlite boulders in glacial overburden in the Kirkland Lake-Larder Lake area (Baker 1982; G. Grabowski, Resource Geologist, Ontario Ministry of Northern Development and Mines, Kirkland Lake, personal communication 1985) suggest that the BRIM area has the potential to host diamonds both in bedrock and possibly in placers associated with eskers in the Quaternary section. The potential for placer gold associated with eskers in the BRIM area is being investigated.

ACKNOWLEDGMENTS

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085. Sedimentology of a Portion of the Munro Esker Complex

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INTRODUCTION

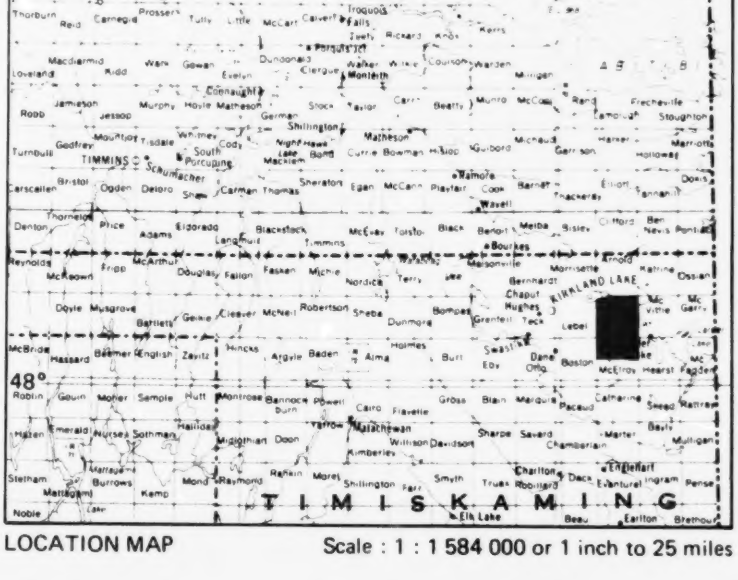
A sedimentological investigation of a segment of the Munro Esker complex within Gauthier Township east of Kirkland Lake was undertaken in order to develop a detailed sedimentological model explaining genesis of the local glaciofluvial deposits. This study was designed as a detailed follow-up to work previously undertaken by Baker (1981). The purpose of this study is to provide basic geological data concerning the depositional processes and characteristics of the Munro glaciofluvial system and investigate methods of using this information for mineral exploration purposes. The Munro Esker is the largest individual esker within the regional esker system of northeastern Ontario. This esker represents an extensive sub-glacial drainage network active during deglaciation.

Reconnaissance level work was also undertaken on the smaller Misema Esker east of the Munro complex. This work was done in order to acquire information for comparison purposes which will further the understanding of the regional subglacial drainage pattern and local esker sedimentation processes.

METHODS

During the course of this research, exposed sediments were studied in ten sand and gravel pits located within Gauthier Township. A Case 580b backhoe/loader with an extendable option was used to dig test pits in areas lacking exposure, and to clear pit faces obscured by large volumes of slumped material. A total of 29 backhoe test pits and 11 pit faces were excavated. A maximum vertical exposure of 3 to 4 m was attainable within each test pit, increasing to 8 to 10 m when excavations were done at the pit face. Planning of the backhoe test pitting operation was done through field investigation and a review of the existing Quaternary geology map (Baker and Storrison 1979), topographic maps, and aerial photographs.

Samples for grain size and heavy mineral analyses were taken from individual sedimentary units. Those units with clasts greater than 2 to 4 mm in diameter were sampled in bulk (up to 40 kg) and sieved in the field using a nest of sieves ranging from 64 mm to 2 mm. Fractions remaining in each sieve were weighed using a triple beam balance, and the frequency distribution was calculated. Material less than 2 mm in size was retained for laboratory analysis. For clasts greater than 64 mm in diameter the clast axes were measured and roundness and shape were noted. Pebble counts were completed on units with a high frequency of clasts greater than 64 mm in diameter. For each pebble count 200 clasts were randomly chosen and identified according to lithology. This data will be correlated with local bedrock geology in order to determined transport distances.



LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

Grain size, heavy mineral, and lithological data will be used in the determination of which hydrodynamic processes were involved in the dispersion, sorting, and deposition of sediments. Such interpretation will aid in the modeling of glaciofluvial transport patterns as they apply to mineral dispersion by glacial and glaciofluvial processes. It will also assist in determining which sedimentary environments are best suited for mineral prospecting.

PRELIMINARY RESULTS

Initial control of sub-glacial melt processes in the study area is attributed to an existing bedrock valley formed along a north-trending fault zone. A portion of this valley has been defined by geophysical survey (Hobson and Lee 1967). That survey traced the valley from Victoria Lake southward to Mousseau Lake. The valley has a maximum width of 3 km and a maximum depth of 107 m. Infilling of the valley by glaciofluvial sediments during regional stagnation and melting of the last glacier lobe produced a complex array of sedimentary facies. Morphologically there is a series of large, north-trending kettles (ice-block depressions), crude lobate forms, and discontinuous ridges. The ridges are prominent at the northern and southern boundaries of Gauthier Township and exhibit similar directional trends. Within the largest ice-block depression there exists a partially obscured or buried, discontinuous ridge indicating the former presence of an englacial or subglacial channel. In order for this channel to survive, full pipe-flow conditions must have prevailed subglacially, allowing the channel to expand laterally and vertically into the ice mass. Large volumes of debris were incorporated into the flow resulting in esker sedimentation.

Deposition of sediment within the Munro Esker occurs in a complex array of environments within the system. These include: 1) the esker proper, formed in a subglacial tunnel or series of tunnels; 2) subaqueous fans, deposited adjacent to the main channel trend as meltwater debouched from tunnel mouths, or overtopped the banks of an ice-walled channel into standing water; 3) braided outwash, deposited at a later stage after infilling of the bedrock valley; and 4) Gilbert-type deltaic deposits representing the subaerial to subaqueous transition of the braided system as it reached the glaciolacustrine environment. During formation of the esker, meltwater was ponded proglacially in Lake Barlow-Ojibway. Localized eolian reworking resulted in the formation of large-scale dunes which mask glaciofluvial features in some situations.

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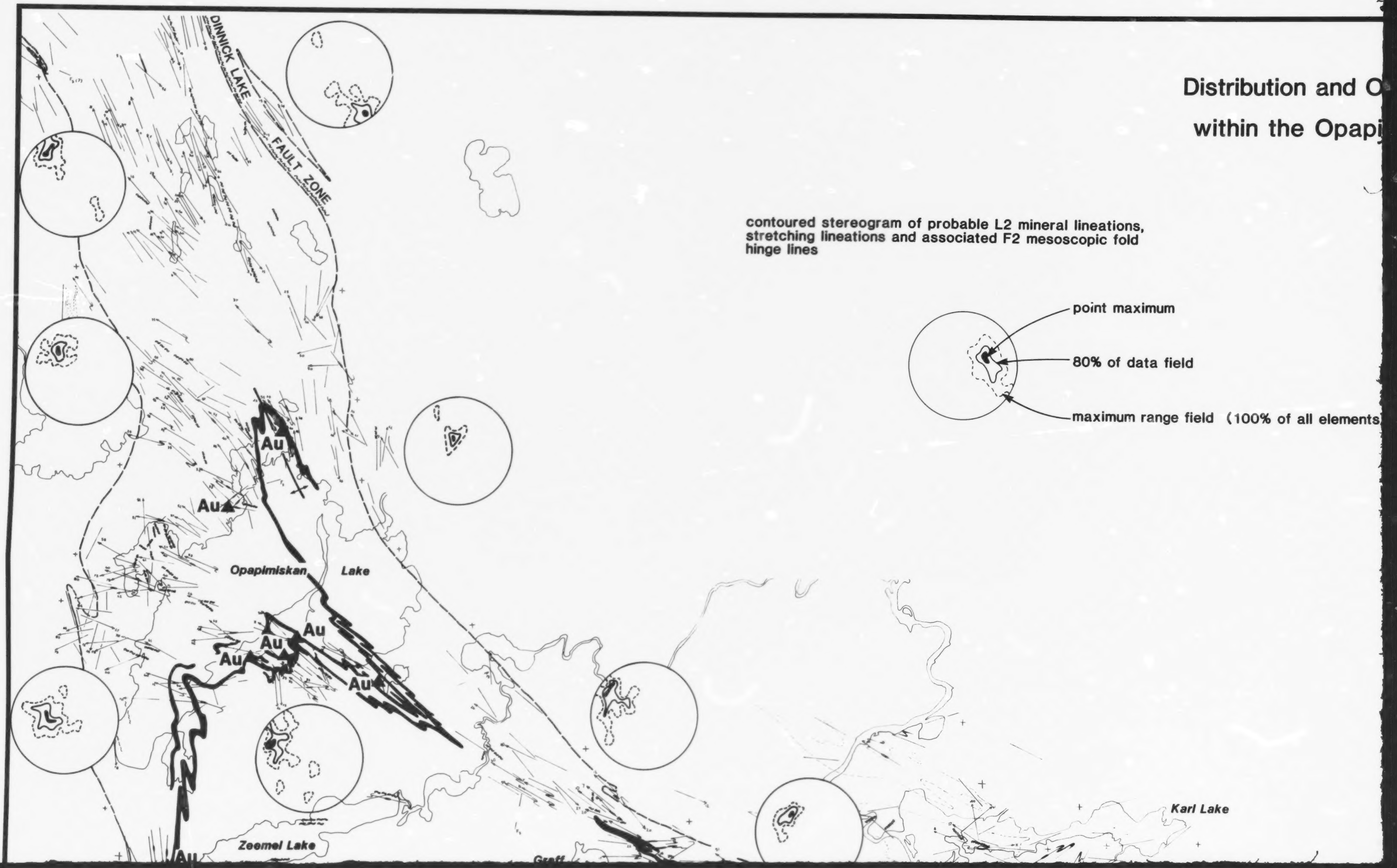
Distribution and O
within the Opapi


DINNICK LAKE FAULT ZONE
Au
Au
Au
Au
Au
Au
Au
Opapimiskan
Lake
Zeemel Lake
Graff
Karl Lake
contoured stereogram of probable L2 mineral lineations, stretching lineations and associated F2 mesoscopic fold hinge lines
point maximum
80% of data field
maximum range field (100% of all elements)

Distribution and Orientation of Major Structural Fabric Elements within the Opapimiskan–Barrigar–Neawagank Lakes Region

ONTARIO GEOLOGICAL SURVEY
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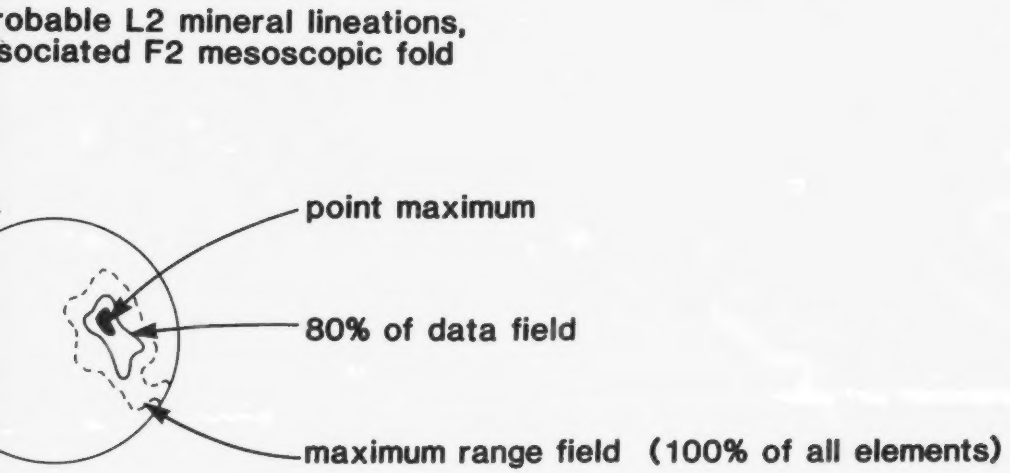
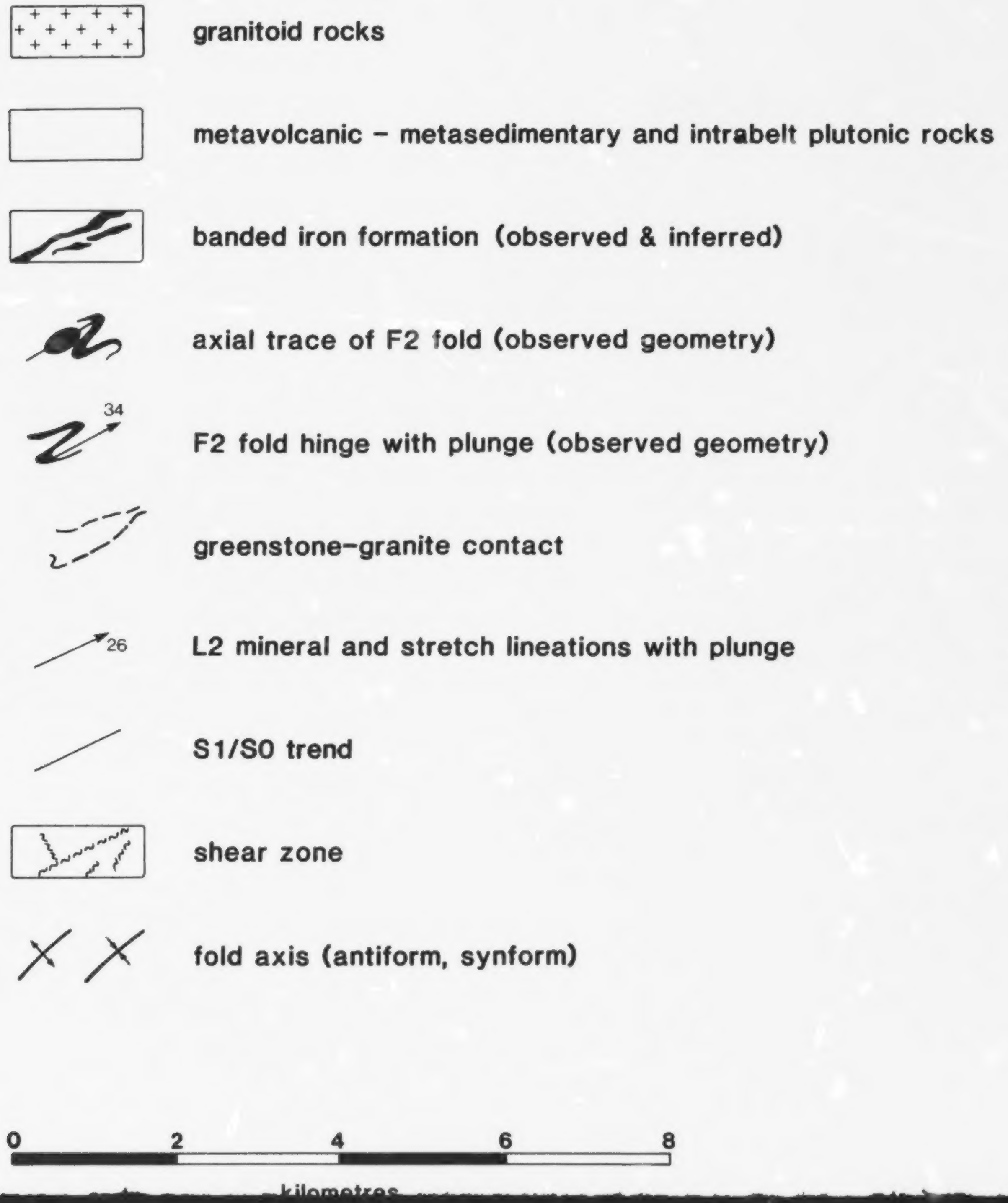
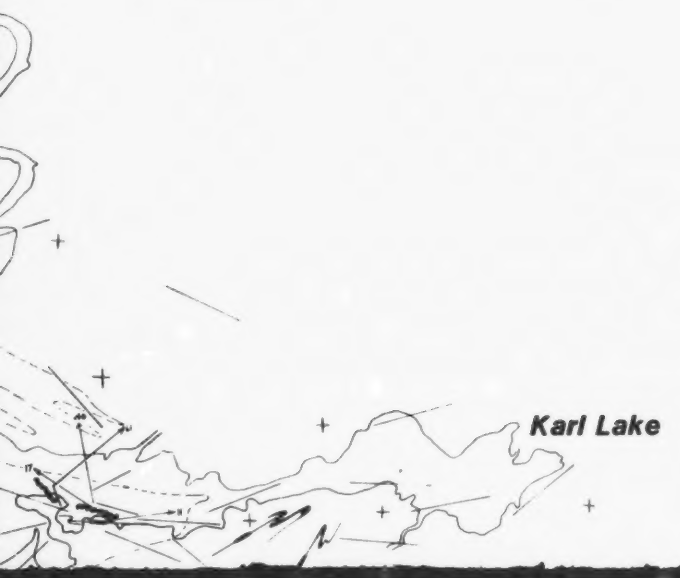
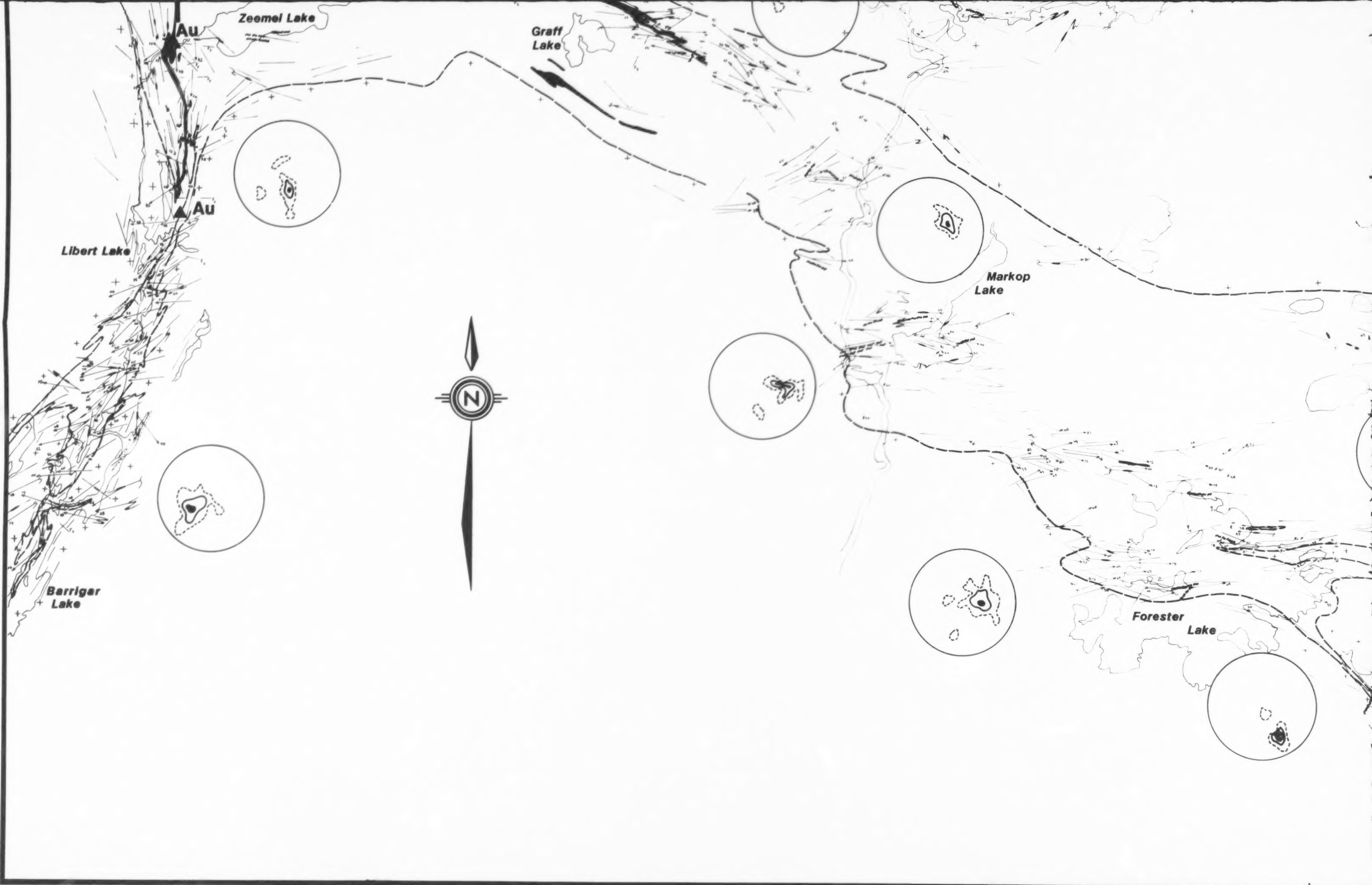
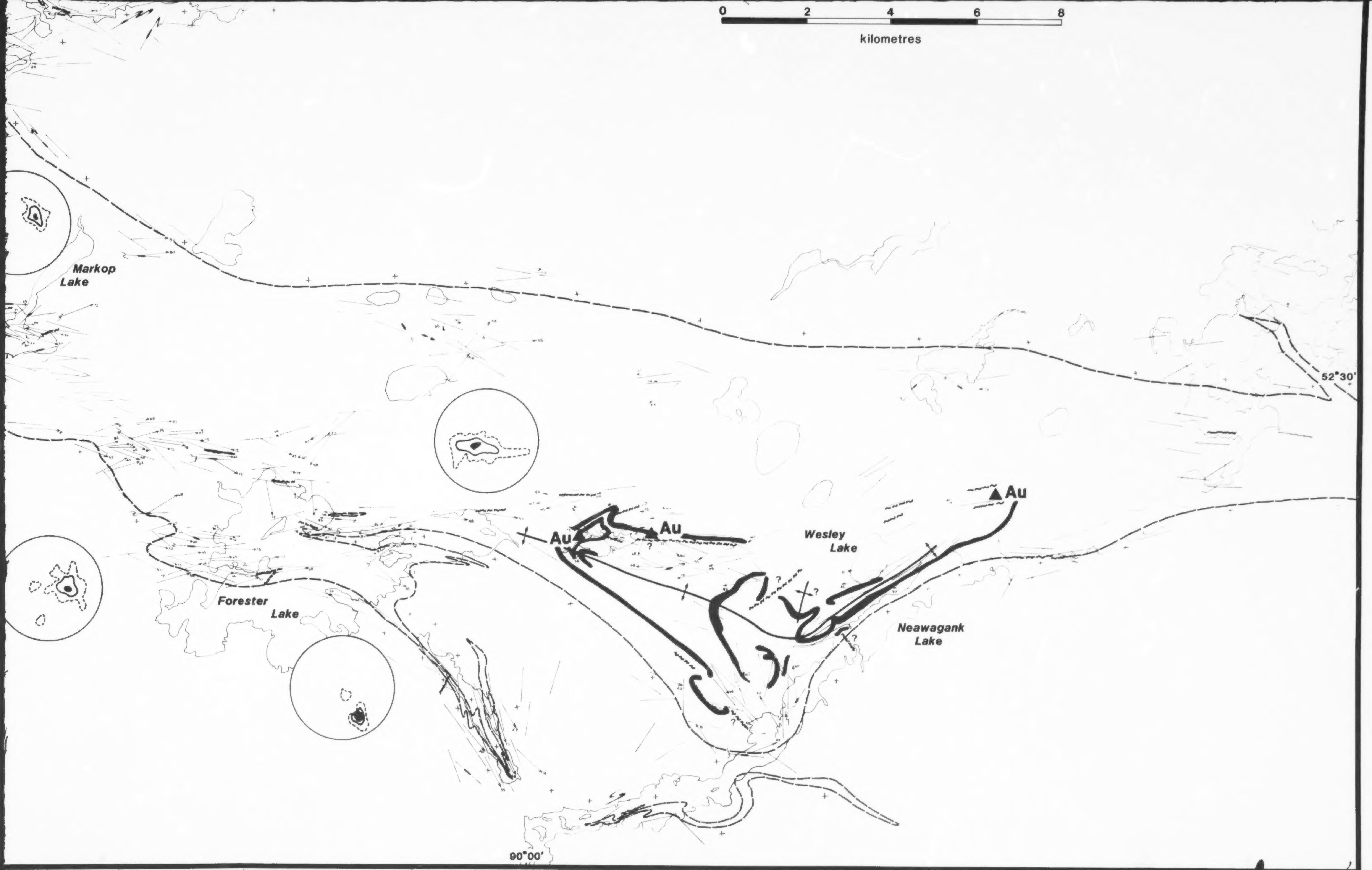
SUMMARY OF FIELD WORK and OTHER ACTIVITIES, 1986
Chart A, Figure 075.4. Distribution and Orientation of Major
Structural Fabric Elements within the
Opapimiskan-&/Barrigar-&/Neawagank Lakes region.
(Accompanies Paper 075).


robable L2 mineral lineations,
sociated F2 mesoscopic fold
point maximum
80% of data field
maximum range field (100% of all elements)


granitoid rocks
metavolcanic – metasedimentary and intrabelt plutonic rocks
banded iron formation (observed & inferred)
axial trace of F2 fold (observed geometry)
34
F2 fold hinge with plunge (observed geometry)
greenstone–granite contact
26
L2 mineral and stretch lineations with plunge
S1/S0 trend
shear zone
fold axis (antiform, synform)
0
2
4
6
8
kilometres




Zeemel Lake
Graff Lake
Au
Au
Libert Lake
Barrigar Lake
N
Markop Lake
Forester Lake


0
2
4
6
8
kilometres
Markop Lake
Forester Lake
Wesley Lake
Neawagank Lake
Au
Au
Au
?
52°30'
90°00'